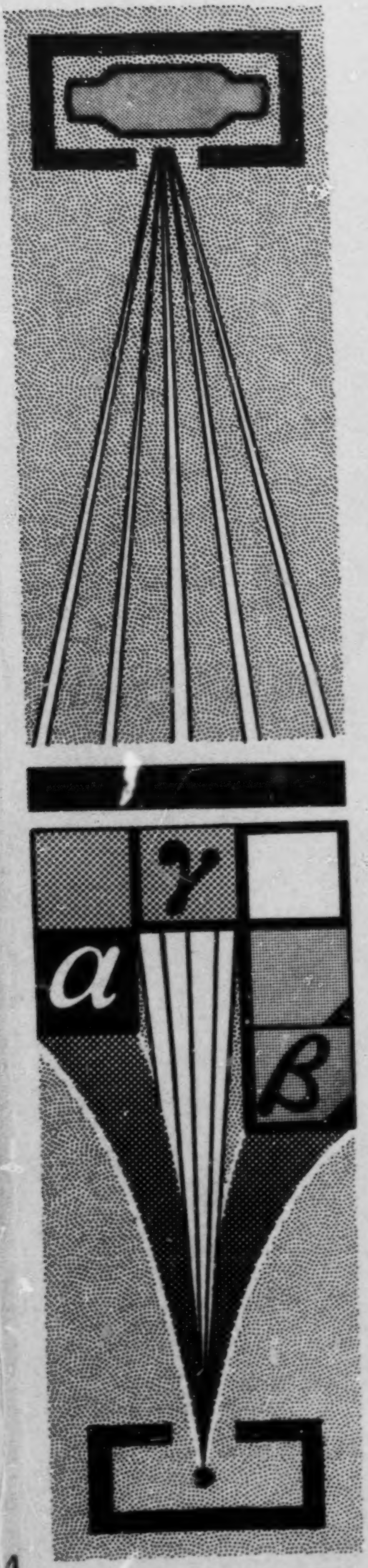

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STATE and FEDERAL CONTROL of HEALTH HAZARDS from RADIOACTIVE MATERIALS other than MATERIALS REGULATED under the ATOMIC ENERGY ACT of 1954

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STATE and FEDERAL CONTROL of HEALTH HAZARDS from RADIOACTIVE MATERIALS other than MATERIALS REGULATED under the ATOMIC ENERGY ACT of 1954

(As of October 1, 1969)

by

George L. Pettigrew
Earl W. Robinson
Gail D. Schmidt

Radioactive Materials Branch
Division of Medical Radiation Exposure

JUNE 1971

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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FOREWORD

This report is one of a series of eight Bureau of Radiological Health staff documents used in the preparation of the "Report to the Congress on Studies Conducted Pursuant to Section 357 of the Radiation Control for Health and Safety Act of 1968, Public Law 90-602." A number of projects were established to study and report on various aspects of radiation control.

The Bureau of Radiological Health implements a national program designed to reduce the exposure of man to hazardous ionizing and nonionizing radiation.

The Bureau publishes its findings in appropriate scientific journals and in division, office and laboratory technical report series and technical note series.

The technical reports and notes allow comprehensive and rapid publishing of the results of intramural and contractor projects. The reports and notes are distributed to State and local radiological health program personnel, Bureau technical staff, Bureau advisory committee members, university radiation safety officers, libraries and information services, industry, hospitals, laboratories, schools, the press, and other interested individuals. The reports are also included in the collections of the Library of Congress and the National Technical Information Service.

I encourage the readers of these publications to inform the Bureau of any omissions or errors. Your additional comments or requests for further information are also solicited.

John C Villforth

John C. Villforth
Director
Bureau of Radiological Health

PREFACE

This report was prepared in fulfillment of Section 357(a)(1) of Public Law 90-602, which directed that a study be conducted of present State and Federal "control of health hazards from radioactive materials other than materials regulated under the Atomic Energy Act of 1954."

This study of State and Federal regulatory control of radium and accelerator-produced materials includes a review of health hazards, a determination of the extent and magnitude of use, and an evaluation of the gaps and inconsistencies in present control of such materials.

The study reveals that radium is still used extensively in industry, medical applications, and consumer products. Despite this widespread use, which dates back many years, radium use is not regulated uniformly by all State and Federal agencies, nor is the control compatible with that exercised over AEC-regulated materials. Furthermore, there is no Federal authority to establish uniform and compatible use standards nor to require that sources and devices containing radium or accelerator-produced materials be manufactured or imported in accordance with minimum product safety standards.

It is hoped that a critical review of this document by responsible agencies and individuals will result in the implementation of comprehensive State and Federal controls over radium and accelerator-produced materials. Such controls should assure the maximum possible benefit from their use while minimizing the resultant radiation exposure to the population.

Arve H Dahl

Arve H. Dahl
Acting Director
Division of Medical Radiation Exposure

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SUMMARY

Radium, a naturally occurring radioactive element utilized since the turn of the century, has had the longest history of use of any radioactive material. It is also more hazardous than most man-made radionuclides. Much of what is known of the biological effects of ionizing radiation in man is based on the crippling and lethal effects of radium ingested by the early watch dial painters.

Although the growth of the use of man-made radionuclides has been dramatic, radium is still very widely used today in medicine and industry, including consumer products. Based upon manufacturers' sales data, approximately 1,300 curies of radium have been sold in the United States. State licensure and registration data indicate that 330 curies of radium contained in 50,000 to 55,000 sources are currently used in medical applications at 2,300 facilities which provide approximately 85,000 medical treatments each year. Nonmedical applications account for about 150 curies at approximately 1,900 facilities in a wide variety of applications.

It is estimated that over 3 million timepieces containing radium are sold annually. The genetic exposure to the total population from radium dial timepieces is probably greater than that from all consumer products containing byproduct material.

In addition to timepieces and sources used in medicine and industry, it is estimated that 200,000 devices and products containing radium are in existence with annual sales of 30,000 units. Examples of the products involved and annual sales include: electron tubes - 13,000/year; fire detectors - 10,000/year; record player brushes - 1,800/year; and educational products - 275/year.

Materials which are made radioactive through utilization of particle accelerators have come into increased use in medicine and industry in recent years. Although current use involves only about 6 curies per year, manufacturers have estimated a 700 percent growth in annual sales by 1971. This growth, apparently, will largely involve medical diagnostic applications.

Radium and accelerator-produced radioactive materials are not subject to Federal regulations. This is in contrast to the complete control exercised by the Atomic Energy Commission over source, byproduct, and special nuclear material. Most States have developed some type of program to control radiation exposure from radiation sources not subject to Federal authority and 21 States (as of October 1, 1969) have assumed some of the AEC's regulatory authority for the control of radioactive materials. Notwithstanding this significant State activity, many States have virtually nonexistent or totally inadequate programs and in 31 States and the District of Columbia, individuals can still purchase radium without proof of competence to handle it safely.

Two-thirds of the companies selling radium devices are located in non-Agreement States and account for 91 percent of the total devices sold. Most of these companies are not subject to government control of the performance and safety of their products. In addition, sales data supplied by manufacturers would indicate that a large fraction of the licensable or registerable radium sources or devices sold in the last few years have not been located by the States.

STATE AND FEDERAL CONTROL OF HEALTH HAZARDS FROM RADIOACTIVE MATERIALS OTHER THAN MATERIALS REGULATED UNDER THE ATOMIC ENERGY ACT OF 1954

(As of October 1, 1969)

INTRODUCTION

Radioactive materials have served as a useful tool in the progress of man for over seventy years. They have and do offer mankind unique opportunities to enhance his existence; however, the same properties which give radioactive materials their usefulness can also offer mankind some of his greatest problems when misused or abused. Recognizing this dual potential, the Congress through Public Law 90-602 has shown its concern over the control of radioactive materials, other than those regulated by the Atomic Energy Act of 1954, and directed the Secretary of HEW to study the matter.

In response to this concern the Department of Health, Education, and Welfare undertook a study of present State[1] and Federal control of such materials to determine:

1. The extent and magnitude of the current use of these materials and their actual and potential hazards,

2. The extent to which adequate controls already exist, and

3. Corrective actions which the Federal government may take to improve and assure control.

This report sets forth the findings of this study.

---

[1] For the purpose of this study the term "State" includes the District of Columbia and the Commonwealth of Puerto Rico.

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BACKGROUND OF REGULATORY CONTROL

All radioactive materials can present potential hazards to people. Exposure of individuals can manifest itself in the form of somatic injuries including leukemia and other malignant diseases, life shortening, and death (1-4). While these effects of radiation are well documented for large exposures, of equal concern is the effect that small exposures to large populations might have on the total genetic pool. Genetic injuries are assumed to occur proportionately to the total, accumulated dose, with no threshold. Therefore, they may appear in the offspring of irradiated individuals, and may not be apparent for many generations. Because of the effect of genetic injuries on future generations, the International Council on Radiation Protection has suggested for total exposure to age 30 for large population groups, ". . . a limit of 5 rems for the genetic dose from all manmade sources of radiation and activities, except medical procedures" (5).

Therefore, the objective of radiation protection programming should be to prevent or minimize somatic injuries and to minimize the deterioration of the genetic constitution of the population. To help achieve this objective, there should be consistent, uniform and all-inclusive control of radioactive materials. Unfortunately, this has not been the case. While strong Federal control has been instituted over some radioactive materials, consistent, effective control has not been nationally applied over others.

Regulation of AEC-controlled Radioactive Materials

The production and/or utilization of radioactive materials used in or produced by means of nuclear fission or fusion processes (byproduct, source, and special nuclear materials) was developed under the framework of complete Federal control. From its inception and for the duration of World War II, the growth of this phase of the nuclear industry in the United States was controlled by the military with the objective of furnishing nuclear explosives for use by the Armed Forces. At the end of the war, control was transferred from the military to a newly created civilian agency – the Atomic Energy Commission (AEC). Through the Atomic Energy Act of 1954, the private sectors of the country were allowed for the first time to participate in the development of nonmilitary aspects of nuclear energy. However, the AEC continued control over the use of these materials to assure the health and safety of the public.

The AEC has regulated and continues to regulate every phase of the process from the time source material is processed through the production, manufacturing, distribution, use, and ultimate disposal cycle. All of these phases fall under a licensure system with the application

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of stringent regulatory controls. Except for certain exempt materials or devices, persons who wish to receive, possess, use, transfer, own or acquire radioactive materials must acquire a license prior to engaging in these activities. There are two types of licenses; specific and general. A specific license requires a specific licensing document, whereas the general license is contained in the AEC regulations and a license application is not required. Specific license applicants are carefully screened for qualifications, proposed use, and adequacy of the radiation safety program. Radiation safety standards which the licensee must meet in addition to the applicable AEC regulations are written into the license and may include any special conditions the Commission deems necessary to protect the public health and safety.

While the AEC has exempted from licensure possession of small quantities of radioactive material and certain devices containing small quantities, and has allowed possession of larger quantities under a general license, all who manufacture and process sources and devices containing radioactive materials are subject to specific licensure. Radiation sources and devices are required to undergo a critical evaluation and prototype testing prior to distribution. Quality control and detailed record keeping requirements are imposed. Consumer products are evaluated from the standpoint of potential individual exposure and the total potential exposure to the genetic pool.

Systematic inspections of licensees are made to determine compliance with the requirements of their license. The reinspection frequency is dictated by the degree of hazard of the licensed material. Enforcement actions are taken to correct noncompliance items.

In 1959, the Congress amended the Atomic Energy Act of 1954 by adding section 274 allowing transfer to States of the AEC's regulatory authority over non-Federal use of source, byproduct and special nuclear material in quantities not sufficient to form a critical mass. The transfer is effected by an agreement between the AEC and the Governor of the State after it is established that the State program is adequate and compatible with that of the AEC. As of October 1, 1969, 21 States (Agreement States) had entered into such an agreement with the Commission.[2] Because of reciprocity provisions in AEC and Agreement State regulations and the legal requirements for Federal – State compatibility in this area, the AEC – Agreement State system of control remains uniform, consistent, and effective.

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[2] Appendix A, table 1, lists Agreement States through October 1, 1969.

Regulation of Non-AEC Controlled Radioactive Materials

The only non-AEC controlled radioactive materials of commercial or health consideration are radium and its daughter products, and accelerator-produced radionuclides. The production of radium in the United States was stimulated in the early 1900's when the U.S. Bureau of Mines undertook with private industry the development of a refining process to extract radium from carnotite ore (6). Unlike the development of atomic energy by the Manhatten project some 30 years later, there was little recognition of the hazards of exposure to radium and radiation protection controls were not instituted by the Federal government. The regulation and control of radium and accelerator-produced materials has been a part of the traditional State function of protecting the health of the public.

While there are several isotopes of the naturally occurring element radium, the one that has found greatest utilization is radium-226, a daughter of uranium-238. Radium-226 is one of the few radionuclides which may be used with its daughter as an alpha-, beta-, or gamma-emitter and, when mixed with beryllium, as a neutron source. Its decay scheme is shown in Appendix A, table 2. It acts like calcium, strontium, and barium chemically and thus tends to concentrate in the bone. This, along with its long half-life (1,600 years), radiation energies, and types of radiation, places it in the highest radiotoxicity group. Because it is an alkaline metal that reacts with nitrogen, it is mainly used in the form of salts. As such, it is easily dispersed under accident conditions. Thus, because of its physical and chemical properties, radium[3] represents both an internal and an external biological hazard to people.

Accelerator produced radionuclides are formed by bombarding a target with a beam of high-energy particles. The selection of the target material and the beam particle determines which particular radionuclides will be produced. It is of interest to note that many of the radionuclides produced through the use of accelerators can also be produced through reactor activation. If produced by the latter method, they would come under Federal control; however, if accelerator produced, the same radionuclides would not be so controlled. Table 3 in Appendix A reflects accelerator-produced radionuclides which have found application in medicine, industry, and research.

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[3] Radium, as used in this report, means radium-226 and its daughter products.

Although a number of States through their industrial hygiene activities had been cognizant of radiation hazards for many years, it was not until the late 1950's and early 1960's that they began to develop specific programs in the radiological health area. The impetus for the development of such programs came from:

1. The concern with radioactive fallout and the need to establish competence at the State level for measurement and evaluation of its public health implications,

2. The growing awareness of the widespread use of X-ray equipment and other radiation sources and the unnecessary radiation exposure that often resulted to members of the general public (such as that from shoe-fitting fluoroscopes),

3. Section 274 of the Atomic Energy Act of 1954 which allows States to enter into an agreement with the AEC to assume certain of the Commission's regulatory authority over radioactive materials. States seeking this authority were encouraged to and generally did develop comprehensive programs to cover all radiation sources, and

4. The development of a more active and effective radiological health program within the Public Health Service which included the establishment of State categorical formula grants, increased State guidance, consultation and technical assistance including short-term training courses and the direct assignment of PHS personnel to State radiological health agencies.

The growth and direction of the various State radiological health programs has not been uniform with respect to the control of radium and accelerator-produced radioactive materials. The types of control programs that have evolved, are based on three essential factors: regulatory approach, standards, and manufacturer control.

Regulatory Approach. Possession and use of non-AEC controlled material in some States requires licensing of the user, in others the registration of the user, and in others no specific requirements. Licensing as noted is a before-the-fact procedure. The potential user must apply for a license and be approved before he may use the material. Thereafter, he is periodically inspected and, if conditions warrant, may have his license revoked. Registration is an after-the-fact procedure. The user notifies the State he is using the material. Depending on the quality of the radiation control program, he may or may not be inspected on a regular basis to determine the safety of his program. For the few States that require neither registration nor licensing there is no legal mechanism to locate or inspect the user.

Among the Agreement States, all but Nebraska and New York have licensing requirements for radium users, although such licensing is required within the regulatory jurisdiction of the New York City Department of Health. Only one non-Agreement State (New Jersey) imposes licensing requirements on radium users. All the Agreement States, as well as New Jersey, license accelerator-produced radionuclides. While it may be possible to institute adequate control without licensing, licensure provides the regulatory agency with a very desirable and powerful legal mechanism to assure the protection of the public health and safety.

Standards. To effectively implement a control program, a State needs enforceable standards relating to the minimum conditions a user should meet. By this is meant such standards as exposure limits and requirements for posting and labeling, leak testing of sealed sources, accountability, and waste disposal. Some States do not yet have minimum standards nor is there uniformity of standards among the States. Model regulations which may be adopted by States are published by the Council of State Governments with the advice of the AEC and the Public Health Service (7). The Public Health Service contributes to the "Model" in the area of radiation sources not subject to AEC jurisdiction which, of course, includes radium and accelerator-produced radioactive material. Since States are not required to adopt the "Model" regulations, some have adopted regulations which differ even in such areas as user radiation safety standards.

Manufacturer Control. All reactor-produced radionuclides are licensed by the AEC or an Agreement State. As a result, the manufacturer of sources and/or devices containing these materials is required not only to handle the radioactive material safely, but also to meet certain requirements related to design, construction, radiation safety analysis, prototype testing, and quality control of the products and undergo periodic inspection of their facility. Therefore, with some confidence, such sources and/or devices may be used knowing they have been manufactured in accordance with safety requirements administered by a competent agency.

Products containing radium on the other hand often represent a problem. Such products manufactured under an Agreement State license are subject to controls similar to those existing over reactor-produced materials. However, no controls exist to insure that products not manufactured under a specific license meet minimum requirements. Without adequate control over the manufacturer, the safety of the product is unknown. Products not manufactured under a specific license can be used in Agreement States; however, such products may be subjected to more restrictive conditions placed upon their use than if they had been manufactured under a specific license. No such protective measure is available in nonlicensing States since they cannot place more restrictive conditions on the use of a product than is enumerated in their regulations. Even if the manufacturer in an non-Agreement State would prefer to have his product manufactured under a specific license to eliminate much of the uncertainty, most Agreement States are reluctant to issue such a license outside their legal jurisdiction. Although Agreement States have licensed out-of-State manufacturers, they cannot inspect the manufacturer's facility and assure the adequacy of his operation.

Additionally, an Agreement State is not required to accept a source or device hazard analysis made by another Agreement State.

All of these factors have resulted in confusion and a lack of uniform and enforceable safety requirements on the manufacturer of non-AEC controlled sources and devices.

CHARACTERISTICS, USES, AND POTENTIAL HAZARDS OF NON-AEC CONTROLLED RADIOACTIVE MATERIAL

This section deals primarily with radium, because of its long history, extent of its use, and the vast amount of information surrounding its use and hazard. However, many of the problems outlined may apply equally to accelerator-produced radionuclides.

Early History

Within two years of its discovery in 1898, some of the biological effects of radium were being noted and reported in the literature (8). The ability of this new material to produce erythema and other biological manifestations gave indications that it might prove beneficial in the treatment of certain medical abnormalities (9-11). As a medical tool, the use of radium steadily grew during the following decades. Paradoxically, while attention was being given to the effect of radium radiation on malignant tissue, little concern seemed evident on the effect this same radiation might have on healthy tissue.

By 1921, however, concern was being voiced over the possible hazard from external exposure to radiation (12). This was precipitated by the deaths of five radiologists from aplastic anemia attributed to exposure from radium or X-rays. Dr. George E. Pfahler, in the first national survey of radiation exposure in 1921, sent a questionnaire to all radiologists in the United States requesting information on their general health and that each have a complete blood examination and wear a dental film in his pocket for two weeks (12). The blood examination would pick up any anemic conditions which might indicate the hazard of radiation exposure while the degree of blackening of the dental film would serve as a rough measurement of the radiation exposure to the radiologist. Pfahler concluded from this survey that "increased protection is needed by those who were working with the gamma rays, or with the higher X-rays," and "complete protection can undoubtedly be obtained. It requires not only the means, but the continual caution on the part of the individual."

A few years later, Dr. R. C. Williams, USPHS, conducted a study of the physical condition of persons working with radium at the National

Bureau of Standards (13). He observed certain blood changes and positive effects upon dental film worn by employees, and in his recommendations suggested that all employees "utilize to the greatest extent all practical protective devices, such as screens, lead-lined carrier boxes, and handling forceps."

The adverse biological effects (health hazards) due to external radiation exposure were generally recognized and in 1925 the first recommendations to limit radiation exposure were made (14). It was recommended that the total radiation dose (maximum permissible dose) received by an individual in one year from X-ray and radium be less than 0.1 of the erythema dose.

Radium Dial Painters

The effects of exposure to internally deposited radioactive material due to the ingestion of radium became known in the mid-twenties when Dr. Harrison S. Martland published his classic findings on "radium poisoning" of the New Jersey dial painters (15-17).

During the years 1917 to 1924, it is estimated that over 2,000 individuals were employed in the luminous dial industry (18). In these facilities, phosphorescent zinc sulphide paint, rendered luminescent through the addition of small amounts of radium-226 and radium-228, was applied to hands and dials of watches, clocks, airplane instrumentation, and so forth. Most of the painters were women and it was often their practice to "tip" the brushes with their lips to achieve a finer point for applying paint. Such a procedure resulted in the ingestion of small quantities of the radium-bearing paint. Over a period of time, the buildup of the ingested radium manifested itself in a variety of medical abnormalities and, in a number of cases, death. Because of a lack of knowledge at this time on the internal effects of radium, little importance was placed on radiation as a possible causative factor; however, as a result of investigations of Martland and others, a cause — effect relationship was shown between radium body burden and clinical effects. The "tipping" practice was quickly abolished as a health hazard. A subsequent study by the USPHS in 1929-1930 indicated that although the "tipping" process had been abolished, radium deposition in workers was still occurring as a result of ingestion and inhalation of the radioactive dust in the work areas (19). The use of radium as a therapeutic agent in tonics also became a questionable medical practice and by 1932 its use for internal administration had been removed from listing in "New and Nonofficial Remedies" of the American Medical Association.

The studies by Martland on the radium dial painters were the basis for our present knowledge of the behavior of the so-called "bone seekers" in the body. The first recommended internal radium body burden limit (0.1 microcuries) was issued in 1941 by the National Committee on Radiation Protection (20). This value is still accepted today.

Studies in 1965 on a group of 62 women that had been employed in the watch dial industry for 5 to 7 years during World War II showed that they had about twice as many lumphocyte chromosomal abnormalities as a control group (21). This was in spite of the tighter controls and lower levels of radium exposure that they were subjected to as compared with the painters of the twenties.

In 1955 Silson, Kleinfeld, and Harris reported two additional deaths associated with the radium dial painting industry (22); however, these deaths by aplastic anemia, were attributed to external rather than internal exposure. Radon breath samples and measurements on the tissues at autopsy showed that internal deposition of radium was negligible in one case and not appreciably above permissible limits in the other. Evaluation of the work histories of these employees indicated that each had a probable high external exposure to radiation. This study tended to emphasize that in addition to controlling the internal hazard, the control of external radiation in the dial-painting industry as a potential hazard should not be overlooked.

Since the initial radium dial painter investigations of the twenties, over 700 cases of individuals with internal deposition of radium have been studied (23). The majority of these individuals were at one time dial painters. Although only approximately 50 cases of death from radium poisoning have been reported, there are undoubtedly a larger number which were not recognized as such and thus not reported. Whereas the early dial painters had fairly large intakes of radium with death primarily a result of aplastic anemia, tumors of the paranasal sinuses, and osteomyelitis of the jaw and other bone structures, later deaths were from osteogenic sarcoma resulting from smaller intakes, with exposure over a long period of time. To date no clinically significant signs or symptoms have been seen in persons with a residual body burden of less than 0.5 microcuries of radium. Above this, there is increasing incidence and severity of symptoms with increasing residual body burden. If the residual body burden of 0.5 microcuries is extrapolated back using a Norris-type relationship (24), the initial radium burden would have been in the 10 to 40 microcurie range; therefore, the radium maximum permissible body burden of 0.1 microcurie originally adopted in 1941 still appears conservative.

Radium Source Characteristics

Radium-226 has been and still is used in a wide variety of products and applications. In most applications radium is used in equilibrium with its so-called short-lived daughters, which include radon-222 through polonium-214 (Appendix A, table 2). The next decay daughter, lead-210 (Ra-D), has a half-life of about 20 years and requires 100 years to reach equilibrium with radium-226. The other long-lived daughter is polonium-210 with a 138.4 day half-life. Polonium-210 and lead-210 are utilized in equilibrium or separated as alpha, beta, or alpha – beta sources.

With regard to the hazard, it is important to note that the first daughter of radium-226, the noble gas radon-222, has the longest half-life (3.8 days) of the short-lived daughters. Thus, it grows into equilibrium with a purified radium salt within 30 days.

In most applications radium is used as a sealed source and the radon is retained within the encapsulating material. When it is used as the activating agent in self-luminous compounds, most of the radon is retained within the crystalline radium salt or the paint adhesive; however, there is some release of radon from luminous compounds and it can also be released from sealed sources as a result of encapsulation failure.

The radioactive daughters of radon are solid elements and plate out on surfaces shortly after they are formed; thus, leaks from radium sources may result in the gradual buildup of radioactive surface contamination from the solid daughters. Lead-210 with a 20-year half-life and its daughters can then be found even many years after the radium itself has been removed.

Of particular significance with regard to the radiation hazard of radium is the fact that radium-226 (and short-lived daughters) is an effective alpha-, beta-, and gamma-emitter which may also be used in a neutron source. Each one of these emissions has been utilized for particular applications; however, with the exception of neutron emission, each of the other three types of emitters are always present and may represent an unnecessary hazard in many of the applications. For example, when radium is used in dermatological applications as a beta source, the gamma radiation results in an unnecessary external exposure to the physician, patient, and to others who may be exposed during the treatment or storage of the source. In any application where radium is used as an alpha, beta, or neutron source, the gamma radiation is an unnecessary external exposure hazard. Conversely, when radium is used as a gamma source, its long half-life, alpha radiation, and chemical characteristics as a bone seeker result in a high radiotoxicity which represents a significant internal hazard. Thus, situations where it may be inhaled or ingested due to source rupture, contamination events, or poor practice are particularly hazardous. Fortunately, in most gamma applications it is possible to use a sturdy encapsulation which makes the probability of rupture low when sources are handled carefully.

As an alternative to using radium, it is possible to use other less hazardous radioactive materials in many applications (Appendix A, table 4); in fact, the decrease in radium usage in the past 10 years has been brought about, in part, by the increased availability and acceptance of these less hazardous materials.

To help define the problem associated with the control of radium and the applications for which substitutes are feasible, it is first necessary to look at the characteristics and hazards from the types of radium sources and devices now being used.

Medical Sources

Needles, tubes, cells, and capsules. These sources are primarily used for the interstitial or intercavitary treatment of tumors. Encapsulation is usually a platinum – iridium alloy with all the alpha and most of the beta radiation attenuated. Although the activity of each source is in the low millicurie range, a number of sources are used for any one treatment. The primary hazards are the external exposure of individuals from one or more of the sources and contamination of people, equipment, or facilities through leakage or rupture of the source(s). Exposure of individuals may be attributed to deficiencies in storing, handling, and accountability of the sources. Leakage or rupture of the source is a function of the source design and construction and the environmental stresses to which it is subjected. Even relatively low releases of radioactive material can result in costly decontamination of facilities and/or equipment. Also such releases can lead potentially to internal exposures to individuals.

Plaques and nasopharyngeal applicators. These medical sources are separated from the preceding ones because the radiation of primary interest is the beta rather than the gamma. To achieve this, a less attenuating medium, such as monel metal, is used for the encapsulation although some of the early plaques used a glazed or ceramic medium. Plaques usually have activities in the range of 5 to 25 millicuries and are intended for the treatment of superficial skin lesions. A typical nasopharyngeal applicator contains 50 millicuries of radium and is used mainly for the treatment of lymphoid tissue. Because of the reduction in encapsulation integrity, both types of applicators are particularly susceptible to rupture and/or leakage due to poor construction, handling, or chemical or physical stresses. Surveys of medical sources have consistently shown that plaques leak more than any other type of source. Nasopharyngeal applicators because of their large length to diameter ratio are subjected to considerable stresses and strains during usage. Both types of source offer potential external exposures in direct relation to their radium content. In addition, patients while undergoing treatment with plaques are often allowed to sit in the waiting room or leave the office. Thus, there is a probability that members of the general public will receive needless exposure from such a procedure.

Radon seeds. Radon gas, released from radium is often collected in fine capillary gold tubing and crimped to form small radon seeds. These seeds can be used as permanent implants in tumors since most of the radioactivity decays in a relatively short period of time. The importance of this method of treatment is recognized for such applications as radiotherapy of bladder cancer, since the permanent implant allows the bladder to be closed immediately. Typical activity of the seeds range from 1 to 2 millicuries with a number of the seeds being used for a given treatment. Although apparent hazard from these seeds is rather minimal, the recent literature has reported that skin lesions have resulted from wearing contaminated gold rings which appeared to have been fabricated partly or wholly from spent gold radon seeds (25-27).

Nonmedical Sources

Logging. Radiation sources are used to determine the characteristics of underlying strata of the earth's surface by lowering a source and detector down an oil well or other exploratory hole. This use is referred to as logging. Two basic types of radium sources are used for this purpose:

1. Scatter gamma sources of 10 to 50 millicuries, and
2. Neutron sources of 300 to 600 millicuries of radium – beryllium.

Encapsulation of these sources is usually adequate to handle the extreme pressures and temperatures to which the sources may be subjected. External exposure poses the greatest potential hazard because of the large activities used, the relative lack of radiation training of the user, and the tendency to overlook or underestimate the neutron hazard.

Radiography. The industrial utilization of radium in radiography, to detect faults in materials, is being replaced by byproduct radioactive materials; however, the sources that are still being used may range up to 150 millicuries. External exposure is the largest potential hazard, although damage to the source by virtue of the environmental conditions under which it is used is also a possibility.

Nonmedical Devices

Gauges. Radium is used in gauges to measure and/or control the level, thickness, density, and moisture of materials. Activities range from 0.1 to 10 millicuries. For moisture measurements radium – beryllium neutron sources are used. Fixed gauges when properly labeled and shielded present little exposure problems; however, many are utilized under environmental conditions which may lead to physical damage of the source and thus release of the radium (i.e., corrosion, vibration, or temperature damage). Portable gauges by their very nature are required to be of light weight. To achieve this, a sacrifice in source shielding is often necessary; therefore, exposure rates near the gauge surface of up to 60 mR/hr are not uncommon. This makes extremity exposure, and to a lesser extent whole body exposure, of particular interest.

Gas chromatographs. Chromatographs are used as a method for determining the chemical components of a sample. The detector cell of this system can employ a radium impregnated gold foil which is covered with a thin coating of palladium. Activities are fairly low, in the range of 22.5 to 100 microcuries. While external exposure problems are fairly small, the foil is particularly susceptible to damage from excessive temperatures, corrosive attack from the sample or cleaning solution, and abrasive damage from cleaning operations; therefore, contamination of equipment and facilities from the release of radium is a potential problem.

Fire detectors. Fire detectors are used in industrial as well as nonindustrial facilities to detect the presence of combustion products such as gases and smoke and provide an early alarm. Radium foils in the range of 0.1 to 40 microcuries have been used in such detectors. The users of these detectors are often unaware of their radium content and usually untrained or unprepared to cope with any actual or potential hazards that may arise. Because of their increasing widespread use, the greatest potential problem is the effect of low radiation exposures to large numbers of the general public.

Static eliminators. These devices are mainly used in industry to discharge static that develops on paper in printing presses and other situations in textile, photographic, and communication industries. Record brushes containing radium as a static eliminator are also sold to the general public. For commercial usage, foil with an activity of 25 to 50 microcuries per linear inch is used with a maximum total activity of approximately 3 millicuries per foil. Physical damage of the foil with a resulting release of radium presents the greatest hazard.

Radium activated self-luminous products. Radium has been widely used to provide luminosity for a large variety of products. While radium alone is not self-luminous, its radiation does act on phosphors to produce visible light. Perhaps its most recognized use has been on timepieces. However, the aircraft industry and the military have been primary users of radium luminous compounds for such applications as luminous markers, instrument faces, dials, and component parts. The activity of products containing radium luminous compounds is low, generally on the order of 0.1 to 5 microcuries; however, because it is used in an unsealed form, as a paint, there is distinct possibilities of ingestion or inhalation of the radium. The greatest potential hazard results from the large number of such products that reach the general public and the accumulating effects they may have on the genetic pool of the population. In addition to timepieces, large numbers of products containing radium luminous compounds have entered the consumer market through government surplus channels with little or no control over final distribution. In most cases the consumer is unaware that the product or timepiece he purchases contains radium.

Radium Hazard Studies

Medical use. As the States became involved in the control of radium, initial emphasis was placed on its use in medical facilities. This area was chosen because:

1. Users would be members of the healing arts who were already licensed by the State. Thus, a potential listing of the users was available and through questionnaires their possession or use of radium could be determined.

2. It was felt that the largest amount of radium was used by the medical profession, and

3. Medical use represented the largest potential for radiation exposure of individuals.

Some of the initial findings of such surveys up through the mid-sixties are shown in table 1. This table gives some indication of conditions existing prior to any attempt at control and the extent to which corrective action needed to be taken. It is probably somewhat representative of conditions in most States prior to an active regulatory program. Inadequate source storage indicates a potential for exposure of physicians, other staff personnel, and members of the general public. For example, a facility in Chicago has such inadequate storage that the dose rate in an insurance office on the floor above was approximately 10 times the maximum permissible level(37). However, the adequacy of the storage area does not tell the whole story. Unnecessary exposures can occur when applicators are loaded or unloaded, during transport to and from treatment areas, during applicator or source insertion, and during patient irradiation. Exposure in these cases depends on the awareness and responsibleness of individuals to take precautions to keep exposure as low as possible.

Table 1. Summary of State initial radium survey results (29-36)

State	Hazardous conditions found			
	Inadequate source storage (percent)	Improper or no labeling (percent)	Leaking or contaminated sources (percent)	Contamination or decontamination required (percent)
Kansas	30	95	50	--
Pennsylvania	44	100	46	--
Alabama[a]	--	--	40	40
Alabama	--	--	43	20
Minnesota	21	--	37	79
Kentucky	10	35	35	--
Georgia	37	87	53	51
New York[b]	20	--	27	--
Indiana	23	--	13	--

[a] Jefferson County only.
[b] Excluding New York City.

Posting radiation areas and labeling radiation sources are important in the safe handling of radioactive materials. Without such indications that radiation sources are present individuals may inadvertently be exposed to unnecessary radiation without being aware of it. In addition, sources have been lost because an individual removed or disposed of unlabeled containers. A problem of larger occurrence with far-reaching implications is the integrity of radium sources. The initial surveys indicated that 13 to 50 percent of the facilities have leaking or contaminated sources. Source leakage serves to indicate that the source encapsulation may be weakened, which could result in rupture of the source. The inadvisability of using leaking or contaminated sources in patients is obvious. Equally obvious is that leaking sources could lead to contamination of facilities and this in turn could lead to contamination of people.

Decontamination cost for medical facilities has ranged as high as \$50,000 (36). An industrial facility contaminated with radium necessitated vacating and loss of the building valued at approximately \$250,000 (36). Not included in the cost is the time expended by State and Federal personnel involved in decontamination activities nor the resulting loss of income by physicians or industry while the facility is undergoing decontamination.

Other incidents which have involved radium include overexposures, losses, and thefts. Losses and thefts can result in needless exposure to individuals and financial burdens (either through decontamination cost or replacement cost of the source). Since 1962, the Bureau of Radiological Health has collected, analyzed, and disseminated information on radium incidents in order to determine their extent and cause, and to devise preventive measures (38). Over 400 incidents have been collected of which sixty-six percent involved losses, virtually all from medical facilities. Most of the occurrences could have been prevented by caution and common sense in combination with good accountability procedures. Sixty-one percent of all reported contamination incidents were caused by the sudden rupture of sealed radium sources. The remainder were caused by leaking sources or careless use of unsealed radium.

Nonmedical use. It can be readily appreciated that any of the problems associated with medical radium sources can apply equally well to nonmedical sources; however, there is far less available information on problems encountered in this area. The largest body of information surrounds the radium dial painting industry. Recently, problems associated with instrument repair facilities, where radium is removed from rather than applied to dials, have been investigated by the Bureau of Radiological Health (39). These facilities are involved with refurbishing instruments, usually from aircraft, which contain radium. The instruments are not labeled as to what they contain and very few of the workers in these facilities are aware that a possible radiation hazard exists. The tear-down and dial stripping operations have produced significant contamination in the facilities where this type of work is done. Similar studies of radium luminising in the United Kingdom have shown that a direct correlation exists between facility contamination levels and radium body burdens of the workers (40).

Efforts are being made to correct the situations that exist in these facilities, however, there are probably others with similar exposure potentials which have not as yet been located.

The extreme environmental stresses which many nonmedical radium sources are subjected to were pointed out in a study conducted by Battelle Memorial Institute (41). Battelle concluded in its report entitled, "Industrial Environmental Conditions of Sealed Radiation Sources" that: ". . . Radium sources were found in some of the most demanding normal environments, including some possibly more severe than by-product sources of the same design and construction would have been approved for. In this connection, failure resulting from normal environmental conditions appeared to be a distinct possibility for some radium source applications. Absence of a requirement for wipe testing at intervals also contributes to the possibility of failure going undetected until significant. Over-all, the comparison of radium sources used industrially with by-product material sources suggests that there is merit in a reasonable control and regulatory program such as has been applied to the latter, and that a comparable approach may be in order for radium sources."

Although States have become more involved in radium control since this statement was made in 1963, there are still many areas where improvements must be made.

Consumer products. 1. Timepieces. The European Nuclear Energy Agency (ENEA) and the International Atomic Energy Agency (IAEA) have adopted standards limiting the maximum permissible radium content of timepieces (42). Unfortunately, no such standard has been established in the United States, either by recommendation or by law. New York City is the only governmental agency that has imposed restrictions on timepieces containing radium (43). With lack of definitive standards, the radium content on a timepiece may vary considerably. Seelentag reported average values of radium content in wrist watches ranging from a low of 0.014 microcuries to a high of 0.36 microcuries; individual values were found up to almost 5 microcuries of radium (44). Table 2 shows a comparison of the estimated annual radiation dose received by critical organs from a wrist watch containing 0.15 microcuries of radium-226 (IAEA recommended maximum radium content for wrist watches) with the ICRP annual limit for body parts (45). It should be kept in mind that the ICRP limits are those for individuals in the population exposed to radiation from all sources, except medical and background. Various foreign governments which have studied population exposure from luminous watches have reported estimated genetically significant doses in the range of 1.2 to 3.3 percent of the natural background (46-48). This genetic dose is probably greater than that from all other consumer products containing radioactive materials combined.

Table 2. Estimated annual radiation dose received by critical organs from wrist watch containing 0.15 microcuries of radium-226 (42)

Organ	Estimated annual dose (mrem)	ICRP annual limit for body part (mrem)
Skin of the wrist	4,800	7,500
Lens of eye	110	500
Blood-forming tissue	30	500
Gonads	10	500

2. Products sold through government surplus. Large numbers of products containing radium luminous compounds including timepieces have entered the consumer market through government surplus channels. Government surplus items are generally not labeled to indicate the presence of radium. Consequently, large qualtities of such items may be stocked in retail surplus stores with little or no suspicion of actual or potential hazard to store employees or customers. A study of 37 retail surplus stores in 1964 by the California Department of Public Health revealed that external radiation levels in areas of some stores were high enough to require designation as "controlled areas" (49). Some of the products containing radium identified during this survey were switches, knobs, buttons, electron tubes, gauges, meters, portable radio transmitters, ship clocks, and pocket compasses. The report of the study concluded that the Federal government should institute effective procedures to keep items containing radioactive materials out of the consumer market.

The BRH has, from time to time, become involved in this problem by its efforts to prevent radium products from entering the consumer market. In 1965, BRH disposed of 300 radium luminous compound kits for GSA (50) and in 1968, was instrumental in preventing the distribution of 3,154 government surplus pocket watches containing radium (51). Subsequent studies on these watches indicated that a person wearing such a watch, under average conditions, would receive an annual dose to the testes of 60 millirems. However, in many cases it is difficult to determine which products or devices contain radium and so the opportunity to prevent them from reaching the general public is lost.

Disposal and transportation hazards. Two problems of a general nature which apply to all types of radium users are: (1) disposal of radioactive material and/or waste, and (2) transportation of radium sources.

Disposal of unwanted or leaking radium sources is often a problem for the user. Although the sources may represent a significant financial investment, the resale market is extremely limited. Disposal through commercial waste facilities is costly; therefore the user may keep these sources, which because of their condition may represent a real hazard, rather than dispose of them at a financial loss. To help the States in the removal of such sources, BRH has for several years provided a free radium disposal service (50). During this time over 970 sources containing 45,400 millicuries of radium have been collected. Some sources received in this manner have undergone physical testing to provide insight into the reasons for source leakage and the parameters of source design needed to prevent leakage. For example, examinations of needles and tubes of various ages has shown corrosion and failure of the encapsulation threads and brazed areas (52). This may indicate a need for improved sealing methods and/or an imposed limitation on the useful life of radium sources.

Many users are unfamiliar with government requirements and regulations concerning the transportation of radium. As a result over the past several years there have been a significant number of radium losses during transit (53). These have resulted in considerable manpower and money being expended by government, both State and Federal, and private industry in attempting to recover the sources. In most cases the loss could have been prevented if the user had complied with the proper regulations.

Summary of Hazards from Radium Sources and Devices

The different types of sources and devices in which radium is used are summarized in table 3. As may be seen, radium is utilized as a gamma source in 5 applications, as a beta source in 2, as a neutron source in 2, and as alpha or alpha — beta sources in 4. Under the health hazards column of table 3, a subjective analysis has been made as to the type of hazard from each source. With regard to the population at risk, "occupational" means exposure to individuals who would normally be considered occupational radiation workers while "public" includes individuals who may be exposed occupationally but where controls to limit radiation exposure are not exercised.

It should be noted that most of the applications which involve products used by nonradiation workers employ radium as an alpha and/or beta source. Although the activity of the source in most of these applications is not great enough to present an acute exposure hazard, unnecessary external radiation exposure does result. Since the use of radium is not presently under complete control in many States, it is difficult to locate all users of such products. This lack of control increases the probability that individuals conducting repair and maintenance on the device may be unaware of the radioactive material content and may damage the source, causing a contamination event and possible internal exposure.

General recommendations with regard to the selection of radioactive materials for use in products such as items 9 through 11 of table 3 are:

1. The half-life of the radionuclide should be shorter than the useful life of the product so that the radioactivity will be reduced when the product is no longer useful,

2. The radiotoxicity of the radionuclide used should be low to reduce any hazards arising from release of the material,

3. External radiation should be sufficiently low that the device does not present acute radiation exposure hazards, the exposure to individuals will be below general public limits, and the total genetic exposure of the population will be insignificant for any one type of device and within guides for all manmade radiation sources, and

Table 3. Characteristics of radium sources and devices

Product or type of source	Activity per source	Type of radiation utilized	Population at risk	Type of exposure			
				External	Internal	Contam.	Remarks
Medical							
1. Needles, tubes, cells, & capsules	1-50 mCi Av. 7 mCi	gamma	occupational public	X X	X	X	acute exposure
2. Plaques	5-25 mCi Av. 5 to 10 mCi	beta	occupational public	X	X	X	acute exposure
3. Nasopharyngeal	50 mCi	beta	occupational public	X	X	X	acute exposure contamination
4. Radon seeds	∿1 mCi	Gamma	occupational public	X		X	gold contamination
Industrial							
5. Well logging	10-50 mCi 300-600 mCi	gamma neutron	occupational occupational	X X	X X	X X	acute exposure acute exposure
6. Radiography	10-150 mCi	gamma	occupational	X	X	X	acute exposure
7. Static eliminators	0.05-3 mCi	alpha beta	occupational public	low	low X	X	consumer products
Products							
8. Gauges	0.1-10 mCi Av. 2 mCi	gamma neutron	occupational	X X	X	X	extremities
9. Gas & aerosol detectors	0.1-105 μCi Av. 20 μCi	alpha beta	public	low	low	low	genetic exposure
10. Gas chromatography	22-88 μCi	alpha beta	public	low	low	low	
11. Luminous compounds	0.01-5 μCi	alpha	occupational	X	X	X	widespread contamination
			public	X	X	X	genetic exposure

4. Radiation exposure should be kept as low as practicable.

The use of radium in these products does not generally meet any of these recommendations. While substitutes are available which present a lower health hazard, one must consider whether the use of the substitute is economically practical in an application that is beneficial to the public.

In the medical use of radium where the medical profession has acquired a body of knowledge demonstrating the beneficial effect of radium treatments, the efficacy of substitutes must also be thoroughly documented. Thus, while it would be impractical to suggest that substitutes be used for all radium applications, it is imperative that radium be utilized under the best radiation protection procedures and controls.

Accelerator-produced Radioactive Materials

The usefulness of a radioisotope for a particular application is determined by its half-life, characteristics of its radiation, and its specific activity. An accelerator-produced radioisotope will often have characteristics which provide it with advantages in specific applications over those which are produced in a nuclear reactor.

A radioactive isotope of an element differs from the naturally-occurring stable isotope of that element in having a different number of neutrons in the nucleus. If this number of neutrons is greater than in the stable isotope, the radioisotope is neutron rich; if less, then it is neutron deficient. Irradiation of stable isotopes in a nuclear reactor leads to neutron rich isotopes which account for more than 50 percent of the known radioisotopes. The remainder which are neutron deficient, cannot, in general, be produced in a nuclear reactor, but must be produced by bombardment of a "target" material with charged particles in an accelerator.

The accelerator-produced radionuclides generally decay by positron emission or electron capture followed by emissions of characteristic X-rays. When positrons lose most of their kinetic energy, they coalesce with an electron in an annihilation process in which the mass of both are converted into electromagnetic energy in the form of two 511 KeV photons traveling in opposite directions making coincidence counting possible with a high degree of spatial resolution and a low background counting rate. Radioisotopes which decay by electron capture hold forth promise in nuclear medicine since the absence of beta radiation, in general, results in less patient exposure in diagnosis.

Many of the accelerator-produced radioisotopes have short half-lives which make their use potentially more desirable than those produced in a reactor in some applications, particularly medical applications since the use of short half-life isotopes also lead to reduced patient exposure. Since larger quantities of these radioisotopes can be safely administered, their use also results in improved measurement accuracy and reduced measurement time.

An additional factor which may give certain accelerator-produced radioisotopes an advantage is that they can be made carrier-free and thus will have a very high specific activity.

The major disadvantages in the use of accelerator-produced radioisotopes are their relatively high cost compared to those which are reactor-produced and the relatively short half-lives of some of them. Although the later is an advantage in one sense (lower dose and increased detectability in medical application) it is also a disadvantage since the source of supply must be located close to the point of use to avoid unacceptable decay of the radioisotope during transport. Such consideration can be overcome if the accelerator is located at the point of use and certain medical facilities are now making their own radioisotopes using an accelerator. The problem can also be minimized by location of accelerators for commercial production near large population centers. Four such accelerators, designed for medical research and isotope production, were in use or planned in 1968 and it is estimated that 20 such facilities may be in operation by 1975 (28).

In addition to medical applications, accelerator-produced radioisotopes have been used in Mossbauer operations, metallurgical studies and several other research applications. Although the use of accelerator-produced radioactive material is at present limited, the use of these materials is expected to grow rapidly in the future, particularly in the area of medical and biological applications. This growth will make the effective control of these radioisotopes imperative.

Conclusion

Radium, like most radioactive materials, can present an external as well as internal hazard. High external radiation exposure to individuals can cause somatic effects, while low external radiation exposure to large groups increases the total genetic load on the population. Internal exposures or contamination of equipment and facilities from released radium can result from faulty design and construction of the sources as well as the environmental stresses the source may undergo.

Many of the problems which differentiate radium from other radioactive materials are a result of its long history of use with little or no control. This lack of prior control has (1) made it difficult to locate all radium and radium users, (2) necessitated educating individuals who had used radium for many years; often with a lack of even the most basic knowledge of radiation safety principles, (3) made it difficult to secure user compliance with appropriate regulations, and (4) necessitated the correcting of problems which had long existed.

Because of the long life of radium sources and the high radiotoxicity of radium, it is imperative that such sources be designed and manufactured using the highest standards and rigid quality control procedures. In this regard, the physical limitations of sources under the environmental conditions in which they are used, as well as the effects that source age may have on these limitations, needs to be more completely evaluated.

In general, accelerator-produced radioisotopes have shorter half-lives than those which are reactor produced. This characteristic provides advantages for many applications, particularly those in nuclear medicine. Although their use is now limited, they will be used in increasing quantities in the future, making their effective control imperative.

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EXTENT AND MAGNITUDE OF THE USE OF NON-AEC CONTROLLED RADIOACTIVE MATERIALS

To delineate the extent of the problem and/or hazard associated with the use of non-AEC controlled radioactive materials, it is necessary to determine the amount of such material being used and the manner in which it is utilized. Toward this end, known or possible manufacturers, suppliers, and importers of radium sources and/or devices, and commercial suppliers of accelerator-produced radionuclides were contacted. In addition, known foreign manufacturers of radium products were requested to supply information on any of their products marketed in this country (See Appendix B). The companies selected for this survey were identified through reviewing Agreement State licenses, manufacturers catalogs, the open literature, and national registers covering radioactive materials and device suppliers. Table 4 summarizes the response from industry.

It is felt that the 88 percent total response for a survey of this nature is extremely good. Of the non-responding suppliers:

1. Two indicated they will supply sales data, but had not at the time of this report,

2. Five are educational suppliers and probably use little or no radium,

3. Four are foreign suppliers, and

4. Three have no particular characteristics.

The companies responding but providing no sales data had either used radium in the past, but could not provide information on the amount used, or had never used radium. The four foreign suppliers not providing sales data did not sell their products in this country. The sixty-five responding suppliers providing sales data probably account for over 95 percent of the non-AEC regulated radioactive material sources and devices sold in this country.

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Table 4. Industrial response

Type of potential supplier	Number contacted	Total received	Suppliers response:			
			1967-68 sales data provided	Prior to 1967 sales data		Indicated no sales
				Provided	Not provided	
Radium source and/or device						
U.S.A.	97	[a]88	49	38	[b]10	25
Foreign	11	7	2	2	1	[c]4
Accelerator-produced material	8	[d]14	7	6	0	0

[a] Some responses covered more than one supplier; however, each company is tabulated here individually.

[b] An additional nine companies are probable past suppliers; however, they supplied data for only 1967 and 1968.

[c] No sales in the U.S.

[d] Seven companies contacted as radium suppliers indicated small sales of accelerator-produced materials.

Source Manufacturers and Suppliers

Table 5 summarizes the response from the ten suppliers of radium sources. While the sales reported for the years 1967 and 1968 are probably quite accurate, sales from prior years and therefore the total sales are low. This is because:

1. The five primary suppliers have been in business from 20 to over 40 years and sales records were not available to cover this time interval. Two companies did give estimates of past sales.

2. The three other primary suppliers did not feel they could ever estimate past sales and therefore supplied information only as far back as it could be readily recovered from company records. In no case did they report sales for years prior to 1961.

Table 5. Radium source sales (10 suppliers)

Type of source	Sales (in millicuries)		
	Prior to 1967	1967 and 1968	Total
Medical	312,810	6,077	318,887
Nonmedical	253,008	9,455	262,463
Luminous compound	543,092	5,558	548,650
TOTAL	1,108,910	21,090	1,130,000

In addition to the approximately 21 curies of radium sold during 1967 and 1968, 42 curies of radon, mainly for medical purposes, were sold during this time interval, and a significantly large number of radium sources were leased (table 6).

Table 6. Radium lease data (1967 – 1968)

Use of sources	Number of companies reporting rentals	Number of sources	Total activity (mCi)
Medical	4	8910	102,774
Nonmedical	4	165	49,185
TOTAL	[a]6	9075	151,959

[a] Addends do not sum to total; some companies rent both medical and nonmedical sources.

The use of accelerator-produced radionuclides as reflected by commercial suppliers is shown in table 7. The potential growth in this area is reflected in that while sales are now approximately 6 curies per year, it is anticipated there will be an increase of 700 percent by 1971. Most of this growth will be in the medical applications area. Because of difficulties involved with supplying short half-lived radionuclides, most sales at present have been of materials with intermediate or long half-lives. However, several of the shorter-lived materials (i.e., yttrium-87 and iodine-123) have sufficient potential applications that it is expected they will account for substantial amounts of the accelerator-produced radionuclides used by 1971.

The total sales or lease of non-AEC controlled radioactive material during 1967 and 1968 is shown in table 8. There were a total of about 227 curies sold or leased during this period of which approximately 154 curies were for medical purposes and 73 curies were for nonmedical purposes.

Table 7. Commercial sales of accelerator-produced radioactive material

			Accelerator-produced materials sales (mCi)		
Use of material	Number of manufacturers contacted	Number of responders	Prior to 1967	1967 and 1968	Annual by 1971
Medical	8	3	1,963	2,972	28,180
Nonmedical	8	5	12,417	8,955	13,304
TOTAL	[a]8	[a]7	14,380	11,927	41,484

[a] Addends do not sum to total; some manufacturers sell material for both medical and nonmedical use.

Table 8. Total sales or lease of non-AEC controlled radioactive materials (1967 – 1968)

	Sales (mCi)		
Type of radioactive material	Medical	Nonmedical[a]	Total
Radium			
Sales	6,077	15,013	21,090
Lease	102,774	49,185	151,959
Radon sales	42,000	-	42,000
Accelerator-produced radioactive materials sales	2,972	8,955	11,927
TOTAL	153,823	73,153	226,976

[a] Includes luminous compounds.

Device Manufacturers and Suppliers

Thirty-seven manufacturers and/or suppliers of devices containing radium responded to the questionnaire. The responses, reported by use category are shown in table 9. Again it is felt that the 1967 and 1968 values are representative of sales during this time interval while the values reported prior to 1967 are low. Twenty-five percent of the companies provided no information on sales prior to 1967. Several of these

Table 9. Reported sales of devices containing sealed radium sources

Type of use	Number of manu-facturers	Activity of source (μCi)	Sales					
			Prior to 1967		1967 and 1968		Total	
			Number	Activity (mCi)	Number	Activity (mCi)	Number	Activity (mCi)
Fixed gauges	6	100-10,000	1,653	668.5	934	2,597.6	2,587	3,266.1
Mobile gauges	7	2,000-5,000	693	2,467	486	1,918.5	1,179	4,385.5
Gas & aerosol	6	0.1-150	46,403	1,689.8	21,167	30.7	67,570	1,720.5
Gas chromatography	2	22.5-88	325	15.4	79	4	404	19.4
Check, std. & calib.	9	1-3,000	321	257.8	1,663	681	1,984	938.8
Electron tubes	3	0.003-3	135,282	120.9	26,319	1.9	161,601	122.8
Other	6	0.5-600	6,974	1,203.4	4,541	36.8	11,515	1,240.2
TOTAL	[a]37	0.003-10,000	191,651	6,422.8	55,189	5,270.5	246,840	11,693.3

[a] Addends do not sum to total; some manufacturers sell devices for more than one type of use.

companies are significant suppliers of devices containing radium from the standpoint of number and/or activity. Included in the "others" category are educational sources, static eliminators on record brushes, and other devices having consumer applications.

Several points of interest may be noted in table 9:

1. While accounting for 65.5 percent of the total number of devices, electron tubes only account for 1.0 percent of the total activity.

2. Gauging devices represent only 1.5 percent of the total number of devices, but 65.3 percent of the total activity.

3. Although sales in 1967 - 1968 account for only 22.4 percent of the total number of devices sold, they represent 45.0 percent of the total activity sold.

4. The range of activities within any one category may vary widely.

Eight additional responding companies used radium in luminous compounds for such applications as timepiece hands and dials, meter dials and pointers, placards, and decals.

It is of interest to note that 22 companies responding to the device portion of the questionnaire are located in non-Agreement States. These companies account for 91 percent of the total devices sold and 81 percent of the total activity sold.

Thirty-three of the responding companies who sold radium in sources and/or devices during 1967 – 1968 provided information on their projected radium use for the next five years. Table 10 presents a tabulation of these responses in respect to anticipated trends in sales, quantity of current sales, and location of the companies. The data indicate a decrease in manufacture of radium devices in non-Agreement States with increase in manufacturing in Agreement States.

Table 10. Expected trends in sales of radium devices during 1970 – 1975

Expected sales trend	Number of companies	Devices sold 1967 – 1968	Company location	
			Agreement State	Non-Agreement State
Decrease	12	1,540	3	9
Remain constant	11	9,361	4	7
Increase	10	20,958	7	3
TOTAL	33	31,859	14	19

Additional information was provided by 46 respondees regarding their practice of leak testing sources or devices leaving their facility and performing prototype testing on each source or device model; However, the degree of effectiveness of the leak and prototype testing and the criteria used were not ascertained. The responses are tabulated in table 11.

Table 11. Manufacturer-conducted leak tests and prototype tests on radium sources and devices[a]

Type of test	Frequency of testing (No. of companies)			No answer or not applicable
	Routinely	Occasionally	Never	
Leak tests	23	5	9	9
Prototype tests	23	1	10	12

[a] Quality and effectiveness of testing were not ascertained.

Current use of Radium Activated Self-luminous Timepieces

Although the survey of manufacturers of radium sources and devices was designed to obtain information on the manufacture of radium activated luminous compounds within the United States, it was not intended to obtain information directly from manufacturers and importers of radium activated self-luminous timepieces. This information was sought separately through contacts with major U.S. producers and both domestic and foreign trade associations.

The total annual U.S. consumption of timepieces since 1962 shown in table 12 is based on data supplied by the United States Tariff Commission (54,55). The apparent total consumption during 1968 was approximately 84 million timepieces.

Table 13 presents the estimated annual U.S. sales of radium activated self-luminous timepieces. Because of the difficulty in obtaining this type of data, it is felt that they are only partially complete, representing a minimum number.

The domestic production of radium activated self-luminous compounds for the period 1967-1968 was 5.558 curies or 2.279 curies per year. Assuming that 1.709 curies (75 percent) was applied to timepieces and 0.5 μCi of radium per timepiece was used, then 3,418,000 new or refinished timepieces could be painted annually. This is consistent with the value

Table 12. Total annual U.S. timepiece production, importation, and apparent consumption, 1962 – 1968 (in thousands of units)

Year	Domestic		Imported		Total apparent consumption		
	Clocks	Watches	Clocks	Watches	Clocks	Watches[a]	Total
1962	25,809	11,919	4,447	13,798	30,256	26,137	56,393
1963	25,053	12,135	4,347	12,745	31,413	24,937	57,350
1964	28,632	11,970	4,758	13,014	33,390	27,353	60,743
1965	29,576	13,609	5,491	17,120	35,067	34,354	69,421
1966	31,673	15,192	6,662	21,597	38,335	42,237	80,572
1967	31,733	16,599	5,704	22,913	37,437	43,294	79,731
1968	31,874	17,110	7,861	23,189	39,735	44,384	84,119

[a] Includes the Virgin Islands and Guam.

Table 13. Total estimated annual U.S. consumption of radium activated self-luminous timepieces (1968)

Type of timepiece	Number of manufacturers or importers	Annual consumption		Estimated total radium content[b] (Ci)
		Domestic	Imported	
Wrist watches	3		496,000	
Pocket watches	1	200,000		0.100
Clocks	3	2,465,000	2,600	1.232
Others	1		510,000	
TOTAL	[a]4	2,665,000	1,008,600	1.332

[a] Addends do not sum to total; some firms sell more than one type of timepiece.

[b] Domestic only.

found. However, the assumption of 0.5 μCi of radium per timepiece may be high. Also the data of table 13 show only radium usage in new timepieces and do not include timepieces refinished with radium luminous compounds.

The AEC-controlled radioactive materials tritium and promethium-147 plus nonradioactive means of dial lighting are replacing radium. According to the Division of Materials Licensing, AEC, 49,435 curies of tritium have been used since 1961 and 11.6 curies of promethium-147 have been used since 1968 in timepieces (56). It can be estimated that approximately 20 million timepieces have been produced using these materials since 1961 and that approximately 6 to 7 million are now produced annually. Thus, although the use of radium in timepieces may have declined, its use is still significant when compared with the use of AEC-controlled radioactive materials.

Radium in Agreement States

As of October 1, 1969, twenty-one States had assumed regulatory control over certain radioactive materials previously controlled by the AEC. Nineteen of these States require that radium, and all require that accelerator-produced materials, be licensed and controlled to the same extent as any other radioactive material. Copies of licensing actions taken by the Agreement States are supplied to the AEC after which summaries of them are printed in the Atomic Energy Clearing House, a weekly publication (57). All past copies of the Clearing House which provide State licensing actions through December 1968 have been reviewed and information pertaining to radium and radon extracted. Information on accelerator-produced materials could not be obtained by this method since the number of radionuclides involved would prove difficult to handle and the method of production of the radionuclides (accelerator or reactor) is not indicated. The information collected through this mechanism appears to be fairly complete for thirteen of the Agreement States, partially complete for three, and incomplete for three (two of which do not license radium or radon). However, the data collected should give a fairly representative picture of specific areas in which radium is being used, how much is used, and to what extent the radium sold is controlled through licensing.

Figure 1 indicates the number of radium licenses issued by sixteen Agreement States; for more detailed information see Appendix A, table 5. Not included are Nebraska and New York, which, except for the jurisdication of the New York City Department of Health, do not license radium, and North Dakota and South Carolina which did not become Agreement States until September 1 and September 15, 1969, respectively. These States, accounting for approximately 32 percent of the U.S. population, show a license density of 21 licenses per million people. This is the same density as found for the nation as a whole including both the Agreement and non-Agreement States. It should be noted that the number of licenses appears to be divided about equally between medical and nonmedical licenses.

Figures 2 and 3 break down the types of medical and nonmedical licenses respectively; for more detailed information see Appendix A, tables 6 and 7. The largest number of medical licenses are issued to private physicians (56.4 percent) with hospitals second (33.8 percent); however, as is represented, the stated address of over one-third of the

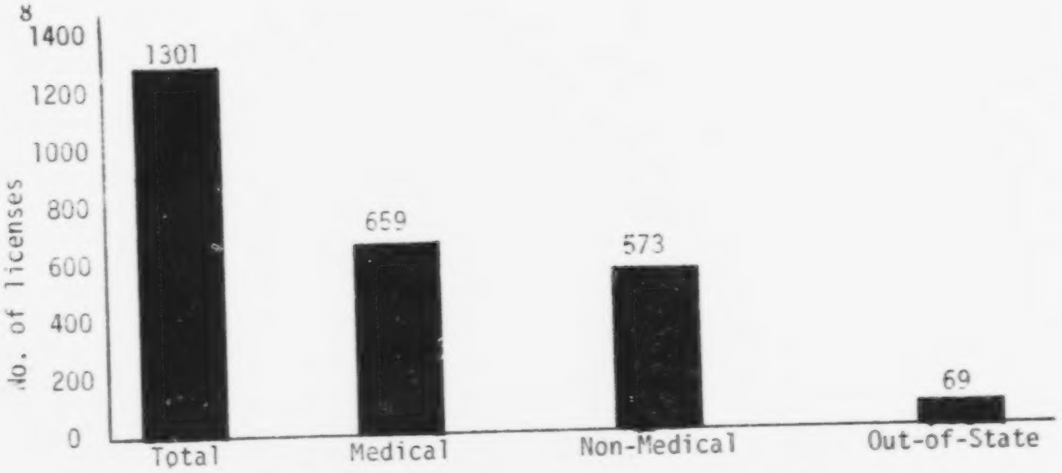


Figure 1. Radium licenses issued in sixteen Agreement States

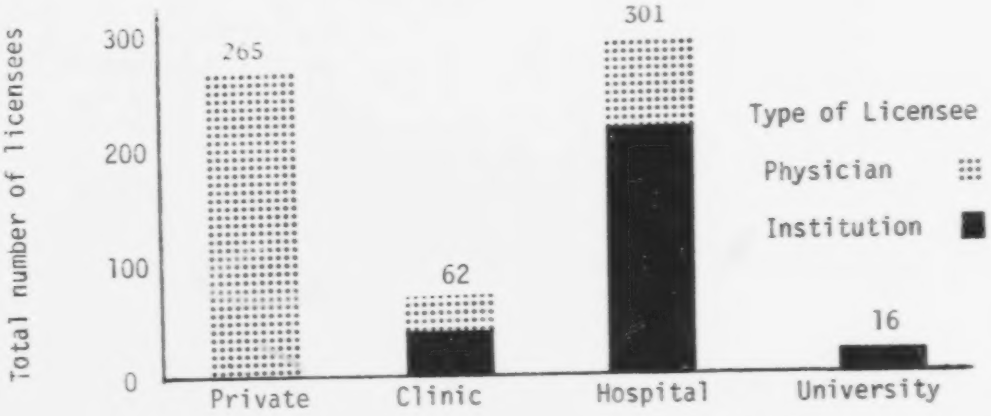
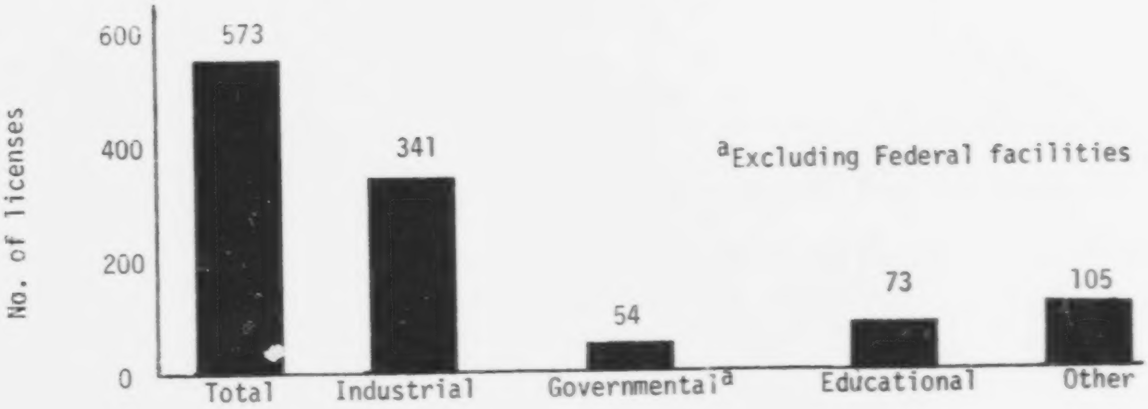


Figure 2. Location of medical radium licensee



licensed physicians is a clinic or hospital. Industry accounts for over 58 percent of the nonmedical licenses; however, the number for government may be somewhat misleading as only State, county, and city agencies are included, Federal facilities being excluded since they are not licensed by State governments. The "Others" number contains a large number of facilities having fire detectors which are only specifically licensed in some States.

Figure 4 indicates the total licensed possession limits for radium and radon in the 16 Agreement States; for more detailed information see Appendix A, table 8. From licenses where both the number of medical sources and the activity were shown, the average activity per source was calculated to be 6 to 7 mCi. Based on this, the number of sources represented by the 101,567 mCi of medical radium would be 14,500 to 16,950. A similar calculation is not valid for the nonmedical sources since, rather than a factor of 10 difference between the lowest and highest activity source as might be found in medicine, a factor of 10^6 exists for the activity range of nonmedical sources; however, from the licenses which did indicate the number of nonmedical sources, it is possible to determine the total number of sources as being well in excess of 10,000.

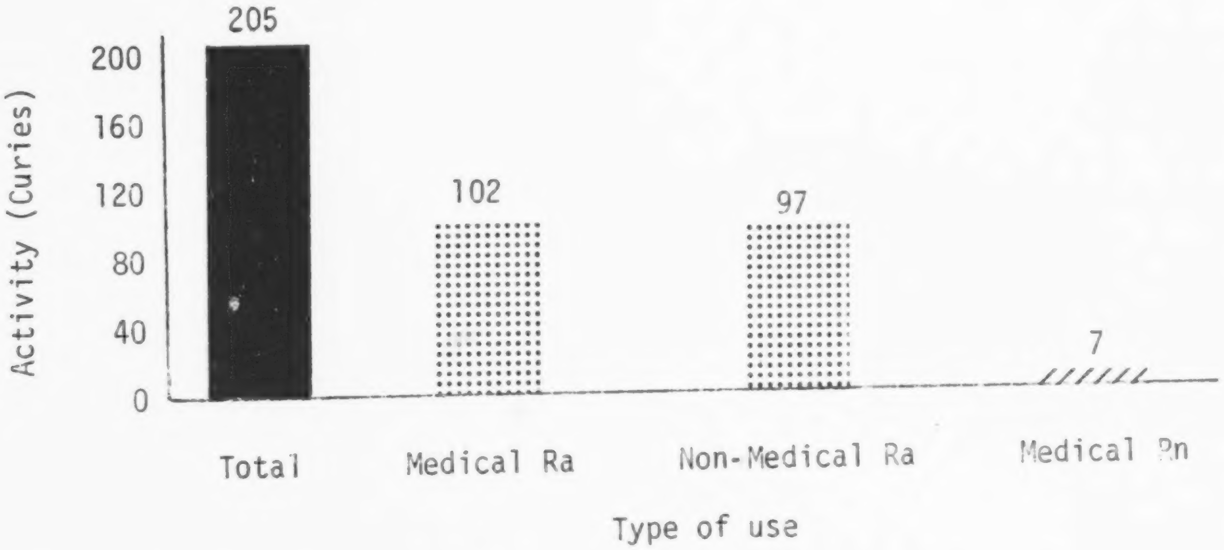


Figure 4. Possession limits on radium and radon sources in sixteen Agreement States.

Use categories and their associated possession limits for nonmedical application are reported in table 14. The largest activities are found in the well logging and research and development areas. While logging accounts for 54 percent of the total activity, its use is confined to only six of the sixteen reporting Agreement States. Similarly, radiography sources involving radium are used in only a small number of States. This is probably due to the increased use of radioactive materials other than radium. The small number of States licensing fire detectors containing radium is a result of difficulties in locating these devices once installed, and a growing tendency to generally license fire detectors.

Table 14. Nonmedical applications of radium in Agreement States

Type of use	Number of States reporting use	Possession limits[b]	
		Number[c]	Activity (mCi)
Mobile gauges	15	201	781.7
Fixed gauges	15	>261	1,253.3
Check, std. & calib.	15	>557	2,655.0
Storage	9	-	8,475.8
Logging	6	>319	52,480.2
Educational	8	-	1,590.9
Research & development	9	-	21,167.8
Static eliminator	6	21	4.4
Gas chromatograph	4	15	0.8
Luminous compound	4	-	3.6
Fire detector	3	973	29.8
Radiography	3	5	1,275.2
Other	12	>5,785	6,879.2
TOTAL	[a]16	>8,137	96,597.7

[a] Addends do not sum to total; all States reported more than one type of use.

[b] No possession limits reported in 35 licenses.

[c] Only those sources specifically identified are reported, a significant number of licenses reported activity only.

The relatively small number of nonmedical radium sources reported by the sixteen Agreement States would appear to indicate the difficulty that is encountered in locating nonmedical radium sources and devices.

Data from Agreement States on Generally Licensed or Exempt Devices

In addition to specific licenses, Agreement States can allow the possession and use of radiation sources under a general license. The general license, effective without the user filing an application, is based on the inherent safety features of the device and/or its low radioactive content and requires little or no radiation knowledge on the user's part.

Most Agreement States require each person licensed to manufacture and/or distribute certain generally licensed or exempt devices to submit periodic reports giving the type of device and the quantity and type of radioactive material sold during the reporting period. Since this information is not reported in the Atomic Energy Clearing House, each Agreement State which licenses radium was requested to provide the Bureau of Radiological Health with data relative to sales of generally licensed or exempt devices containing radium. Table 15 is a tabulation of the data received. Only 12 States responded to the request and of these, 2 reported that there were no general licensees in their State and 2 could not or did not supply data.

Table 15. Summary of certain generally licensed or exempt devices containing radium sold or manufactured in Agreement States

Type of device	Number of States reporting data	Number of sources	Total activity (mCi)
Fire detectors	5	4,039	14.6
Vacuum gauges	2	594	59.4
Other gauges	3	28	26.2
Liquid scintillation	4	44	0.8
Others	2	4	20.5
TOTAL	[a]8	4,709	121.5

[a] Addends do not sum to total; some States reported data on more than one type of device.

There is some indication that the requirement for a periodic report from manufacturers of generally licensed or exempt devices is not being systematically enforced. One State radiological health program director wrote: "Based on a review of our records, I will be unable to supply the requested information. I was unable to find any records prior to 1967 and those records after 1967 were so incomplete that a tabulation would be meaningless. I believe this indicates that there is very little control over generally licensed devices. In fact, a general license almost appears to be an exemption from licensing. . ." Therefore, the data reported herein on generally licensed or exempt devices should be considered as only partially complete.

Radium in Non-Agreement States

Radiological health agencies in nine non-Agreement States representing 58 percent of the non-Agreement State population were requested to supply basic data on known amounts, types, and uses of radium for their respective States. Seven States, representing 38 percent of the non-Agreement State population, responded; however, the data submitted by one of these States was only partially useful in this study. Table 16 tabulates the amount of radium registered in the responding States by type of radium facility; for more detailed information see Appendix A, table 9.

Table 16. Summary distribution of radium sources by facility type in certain non-Agreement States

Facility	Facilities		Sources[a]		Activity	
	Number	Percent	Number	Percent	Millicuries	Percent
Medical	634	61.0	10,949	67.4	82,253	85.7
Industrial	299	29.0	3,598	22.2	11,428	11.9
Government	24	2.3	214	1.3	208	0.2
Educational	62	6.0	1,458	9.0	1,074	1.1
Other	17	1.7	21	0.1	1,025	1.1
TOTAL	1,036	100.0	16,240	100.0	95,988	100.0

[a] Owned or long-term leased only.

Table 17 presents a summary tabulation of radium used in medical practice; for more detailed information see Appendix A, table 10. When the maximum quantity of radium possessed at any one time was not known, estimates were made using an average value determined for each respective State based on the owned or long-term leased sources within that State. For short-term or "per case" leasing, an average maximum value of 100 millicuries of radium was assumed. The distribution of type of medical radium sources shown in table 18 is based on activity; for more detailed information see Appendix A, table 11. From these data, the following information was obtained:

1. In medical practice, 1,689 mCi of radium per million population is used, with a range from 1,169 to 2,300 mCi.

2. There are approximately 9.65 hospitals and 3.37 clinics or private medical offices using radium per million population. This is very dissimilar from the distribution of facility types found in the Agreement

States (fig. 2). This may be due to the fact that many of the larger non-Agreement States in this sample have made efforts to get physicians to store their radium at a hospital rather than at their private office. The State then registers or licenses the hospital and not the physician.

3. Hospitals use an average of 150 mCi and clinics and private medical offices use an average of 72 mCi of radium. The total average was 130 mCi of radium per facility. This difference in radium possession results from the fact that therapeutic procedures performed in hospitals generally require larger amounts of radium than those performed in clinics or private offices.

4. Twenty-three percent of the hospitals and 4 percent of the clinics or private medical offices or 18 percent of all medical facilities lease radium on a short-term or "per case" basis. Medical facilities which lease radium only occasionally do not have the problem of continuous storage; however, they may be less well equipped to handle the radium during source or applicator preparation, use, cleaning, and disassembly. Persons who lease radium on a short-term basis may also be more prome to fail to comply with State registration requirements.

5. Needles, tubes, and cells account for 94.5 percent of the radium used in medical practice; however, it was found that 14 percent of the medical facilities used either plaques or nasopharyngeal applicators. Therefore, the use of these sources, for which better substitutes are available, is still fairly widespread.

Table 17. Summary of medical radium possession in certain non-Agreement States[a]

Type of user	Type of possession		Total
	Own or long-term lease	Short-term lease	
Number of facilities			
Hospital	361	109	470
Private	157	7	164
TOTAL	518	116	634
Number of sources			
Hospital	9,818	-	-
Private	1,131	-	-
TOTAL	10,949	-	-
Total activity (mCi)			
Hospital	59,304	11,075	70,379
Private	11,174	700	11,874
TOTAL	70,478	11,775	82,253

[a] Based on States having a population of 48.7 million.

Table 18. Distribution[a] of medical radium sources by type of source in certain non-Agreement States[b]

Type of sources	Hospitals (percent)	Clinics and private offices (percent)	Total (percent)
Needles, tubes, and cells	85.7	8.8	94.5
Plaques	0.6	0.7	1.3
Nasopharyngeal applicators	1.2	3.0	4.2
TOTAL	87.5	12.5	100.0

[a] Distribution based on the radioactivity of the sources.

[b] Representing a population of 38.5 million.

The types, number, and total activity of nonmedical sources are shown in table 19; for more detailed information see Appendix A, table 12. An examination of the data on a State-by-State basis shown a wide variation in the number of sources of a given type registered with only mobile gauges and calibration and reference sources being reported by all States. In the case of the gas and aerosol detectors, 92 percent of the devices were registered by two States. The four remaining States may exempt such devices from registration or may not have located all such devices in their States.

As would be expected, well logging sources are not prevalent in these States which have limited petroleum production.

Table 19. Nonmedical radium sources in certain non-Agreement States[a]

Type of use	Number of States reporting use	Possession	
		Number	Activity (mCi)
Industrial radiography	4	9	1,150
Well logging	2	15	116
Calibration and reference	6	194	455
Fixed gauges	5	289	405
Mobile gauge	6	63	91
Static eliminator	5	232	342
Gas and aerosol detector	4	2,213	101
Gas chromatography	4	23	2
Other (and not identified)	6	1,767	2,011

[a] A total of 6 States representing a population of 38.5 million are used in this tabulation.

Radium Usage in the United States

Based on the data collected through Agreement State licenses and the non-Agreement State survey, an estimation of the total amount of located radium used in the country and how it is utilized is possible. The estimation, made on a population basis, will tend to overestimate the amount of radium that has been actually located but will underestimate the quantity of radium in actual use because:

1. Agreement States specify possession limits rather than actual amount of radium used,
2. projections will be based on data from Agreement States and selected non-Agreement States whose programs should be above average, and
3. only sources which would be specifically licenses or registered would be included.

Table 20 indicates the total number of radium facilities and total quantity of radium in the United States based on such a projection. For comparison the amount of radium sold and leased as reported by the manufacturers and suppliers is also shown.

Table 20. Estimated total number of located radium facilities and quantity of radium in the United States (1968)[a]

Type of user	Number of facilities[a]	Total activity[a] (curies)	Total activity reportedly sold or leased[b] (curies)
Medical	2,280	326	421.7
Nonmedical	1,850	148	311.6
TOTAL	4,130	474	733.3

[a] Exclusive of Federal use.

[b] Excludes luminous compounds.

The estimate of located radium facilities and quantity of radium in the country would only include those which would require specific licensure or registration. There is an undetermined number of facilities that possess generally licensed devices or exempt quantities of radium. Also excluded from table 20 are radium usage by Federal agencies which has been significant and radium luminous compounds which, as indicated by the manufacturers, have accounted for just under one-half of the total amount of radium sold. The 4,130 facilities possessing radium is approximately 25 to 30 percent of the total number of facilities using byproduct materials (including both AEC and Agreement State licenses). Most of the remaining radium not accounted for by the States can be attributed to disposal of unwanted sources and devices, and radium returned to the manufacturer.

It is felt that most of the medical users and other users of large quantities of radium have been located. The largest number of sources that have not been located are probably those in the low millicurie (or microcurie) range. Therefore, their total activities would not significantly change the projected total activity in the country.

Based on a population projection of the Agreement State and non-Agreement State data, the number and activity of nonmedical radium sources that might be expected to be found in the United States in twelve different categories are shown in table 21. A number of devices using radium are exempt or under general licensure and thus do not show in the table.

Table 21. Estimated use of radium for nonmedical applications in the United States (1968)[a]

Type of use	Estimated in the United States	
	Number	Activity (mCi)
Mobile gauges	514	1,695
Fixed gauges	>1,070[b]	3,220
Check, std. & calib.	>1,460[b]	6,040
Storage	-	12,700
Logging	-	62,600
Educational	-	5,030
Research & development	-	33,800
Static eliminators	463	706
Gas chromatographs	74	5
Fire detectors	6,200	254
Radiography	27	4,720
Others	14,700	17,300
TOTAL	>24,508	148,070

[a] Excluding generally licensed or exempted usage.

[b] A significant number of licenses of this category recorded only the activity possession limit and did not include the number of devices or sources.

Because of this, direct comparisons of projected data with manufacturers sales data for each category is not possible; however, a relative comparison can be made. Based on the data in table 21, it would be expected that approximately 25,000 nonmedical devices are licensed or registered in this country. Data from only nine manufacturers of devices, whose use should require either licensing or registration, have reported sales of approximately 50,000 such devices. Therefore, it can reasonably be expected that the total number of devices which should have been located is far in excess of those which actually have. A comparison between tables 9 and 21 indicates that a large number of small activity devices have not been found. Without information from the manufacturer on who had purchased the device it would be virtually impossible for a State to locate many of these devices. In addition to finding use in almost any industrial or research facility, devices such as fire detectors have been found in schools, churches, museums, and other buildings.

Extent of Radium use in Medical Practice

As previously stated, approximately 326 curies of radium-226 and annual sales of 21 curies of radon-222 are being used at 2,300 **hospitals** clinics, and private medical offices in the United States. To determine how frequently radium and radon are used in medicine the Bureau of Radiological Health contracted with the Stanford Research Institute (SRI) to answer this and other questions concerning the magnitude of the diagnostic and therapeutic use of radioactive materials in medical practice (58).

The study conducted by SRI consisted primarily of a questionnaire mailed to physicians licensed to possess and use radioactive materials or registered with State radiological health agencies as possessing such materials. The names and addresses of these physicians were obtained from the Atomic Energy Commission and State agencies.

Based on the data obtained it can be estimated that during 1966, when the study was conducted, approximately 85,000 radium and radon treatments were provided to 61,500 patients. This compares to 33,310 brachytherapy treatments during the same period using byproduct materials, the majority of which were treatments of the eye using strontium-90 plaques; for more detailed information see Appendix A, table 13.

The distribution of physicians who performed various types of brachytherapy treatments using radium is shown in table 22. As would be expected, 75 percent of the physicians using radium treat intracavitary lesions. Forty-seven percent provide only this type of treatment. Most intracavitary use is for treatment of cancer of the cervix – uterus in which 80 to 130 millicuries of radium are used during treatment times which may range up to one week in duration.

Table 22. Percent of physicians providing specified radium treatment type.

Treatment type	Percent[a]
Interstitial	38
Intracavitary	75
Nasopharyngeal	9
Dermatological	15
All others	1.2

[a] 29 percent of the physicians provided more than one treatment type.

Treatment frequency distributions for these major treatment types are shown in figure 5. Most physicians provided less than 25 treatments of each type annually. However, a few physicians providing large numbers of treatments tended to raise the means to unrepresentative values.

Conclusion

It has been determined that over 227 curies of non-AEC controlled radioactive materials were sold or leased during 1967 and 1968. While accelerator-produced materials are now used mainly for tracer studies, both industrial and medical commercial suppliers foresee an increase in sales of 700 percent in the next two years. The sale of radium sources and devices is probably decreasing. However, the 4,130 facilities now using radium and/or radon represent a significantly large group of users. Radium-226 is more widely used than any other highly radiotoxic radionuclide and is one of the most widely used of any radionuclide. The estimated 326 curies of radium used in medicine account for 47,000 to 55,000 discrete sources and along with radon provide over 85,000 medical treatments in 1966. This is almost three times as many brachytherapy treatments as provided using byproduct material over the same period of time.

Most of the nonmedical radium is used for well logging sources and in research and development; however, large numbers of small activity sources are found in devices such as fire detectors, mobile and fixed gauges, electron tubes, static eliminators, and gas chromatographs. While it is felt that most of the larger sources and/or users have been located, large numbers of the smaller sources and devices apparently are still unaccounted for. This is significant in that the genetic exposure

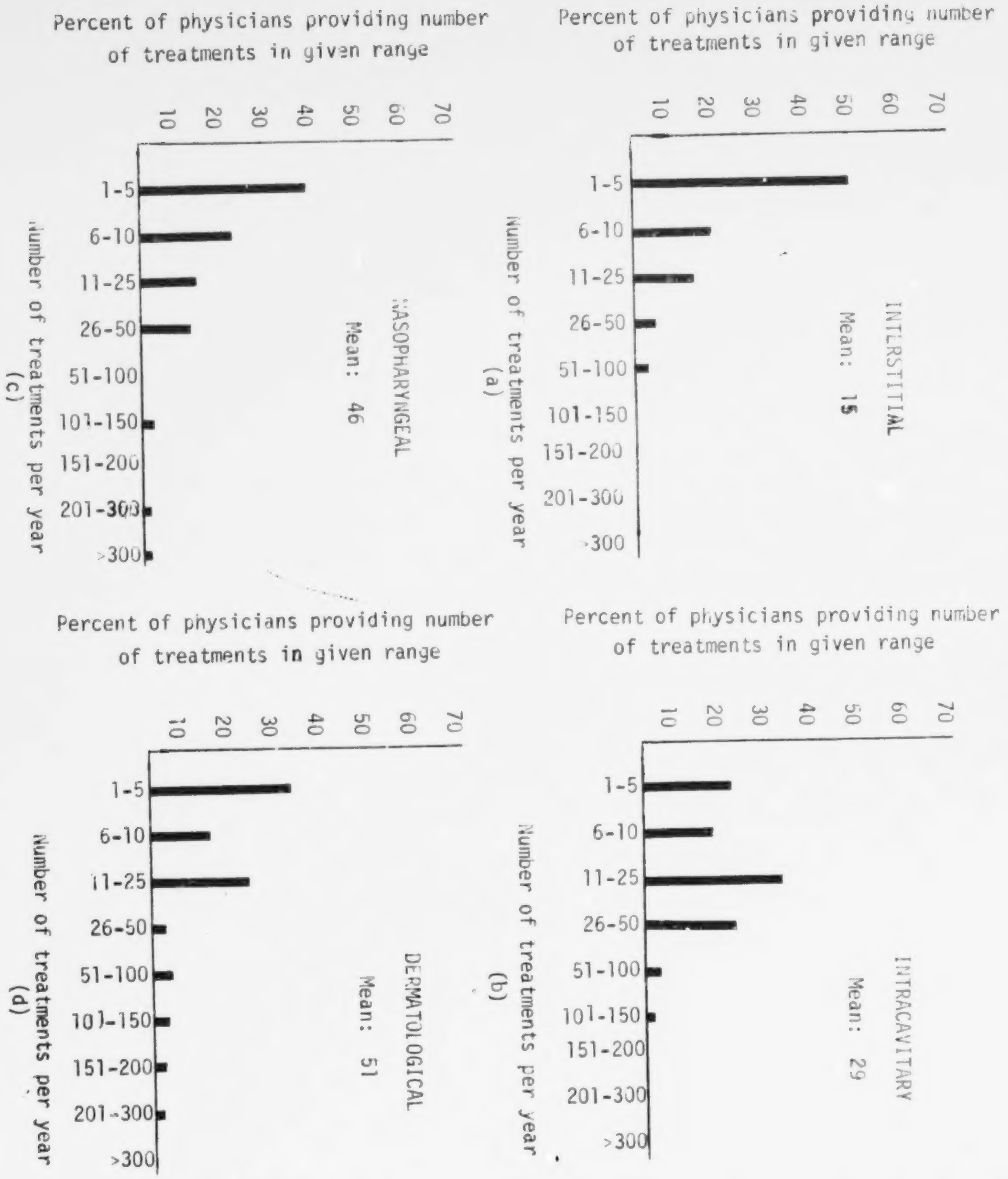


Figure 5. Radium brachytherapy annual treatment frequency distributions

to the total population may be more affected by these sources than the larger ones. Radium continues to be used in luminous compounds although other less hazardous substitutes are available. Apparently large amounts are still utilized in consumer products such as watches and clocks. Even with the increased control over radium by State health agencies, it continues to be the least controlled of the hazardous radioactive materials.

STATE CONTROL OF HEALTH HAZARDS FROM NON-AEC CONTROLLED RADIOACTIVE MATERIAL

Legislation and Regulations

As previously indicated, State radiological health activities began to develop systematically in the late 1950"s and early 1960's. The current status of State legislative authority and regulations for the control of radium and accelerator-produced material is shown in table 23. Forty-four States now have specific enabling legislation for the control of ionizing radiation; however, eight of these have not promulgated regulations for the control of radium and accelerator-produced radioactive materials. Of the 8 States not having specific enabling legislation, 5 have promulgated regulations under their general health laws. Therefore 11 States do not have regulations for control of non-AEC controlled radioactive materials.

Table 23. State legislative authority and regulations for control of radium and accelerator-produced radioactive material

Legislative authority	Number of States	Have promulgated regulations	
		Yes	No
Specific legislation	44	36	8
General health laws	8	5	3
TOTAL	52	41	11

Even though 41 States have such regulations, only approximately 60 percent of these have regulations which are equivalent to or compatible with the Council of State Governments Suggested State Regulations for Control of Radiation (7) in the area of radiation safety requirements during the use of radioactive materials.

State Resources

The growth of State radioactive material control programs as reflected by fiscal and manpower resources is shown in table 24. PHS formula grants for radiological health are also shown in table 24. It can be seen that those grants were effective in promoting State program growth during Fiscal Years 1962-1965. However, even though the direct formula grants declined from Fiscal Year 1965, total State expenditures continued to increase up to Fiscal Year 1967 but began to decline when the direct formula grant program ended. However, discounting PHS grants, the States doubled their total radiological health expenditures from Fiscal Year 1962 to Fiscal Year 1967. While the total of all radiological health expenditures and man-equivalents has increased by a factor of 2.78 and 1.85 respectively, the radioactive material program expenditures and man-equivalents have increased by a factor of 6.45 and 3.62 respectively.

Table 24. Total expenditures and personnel man-equivalents of State and local radiological health agencies

Fiscal year	Man-equivalents		Expenditures (millions)			Agreement State population (millions)
	Total	Radioactive materials[a]	Total[b]	PHS Formula Grants	Radioactive materials[c]	
1962	236.6	27.6	2.62	-	0.29	3.2
1963	311.8	41.1	3.22	1.49	.59	52.7
1964	375.2	60.9	5.34	1.99	.95	54.7
1965	436.8	75.9	6.20	2.49	1.28	67.6
1966	444.2	79.5	6.82	2.42	1.39	74.0
1967	445.0	83.7	7.44	2.16	1.61	87.1
1968	438.7	94.1	7.38	(d)	1.81	89.1
1969	437.0	100.0	7.29	(d)	1.87	89.8

[a] Does not include PHS State assignees.

[b] Includes PHS formula grants.

[c] Expenditures and man-equivalents in radioactive materials control include a proportionate share of that devoted to basic planning and administration.

[d] Formula Grants were replaced by comprehensive health planning grants.

The growth in State responsibility for the control of radioactive material formerly under the jurisdiction of the AEC as reflected by the growth in Agreement State population can also be seen in table 24. The increase in population of such States roughly parallel the increase in both the radioactive materials program man-equivalents and expenditures.

Table 25 compares current Agreement State and non-Agreement State expenditures and manpower including licensing, registration, and inspection data. Data for Fiscal Year 1968 were used since the study of State radiological health programs conducted in Fiscal Year 1969 did not include certain information needed in table 25. Also included in this table for comparison are Fiscal Year 1962 expenditure and manpower data. The Agreement States used in this analysis were those that had attained agreement status as of July 1, 1968 (18).

Table 25. State radioactive materials control program data

Item	Agreement States as of 7-1-68		Non-Agreement States as of 7-1-68	
	FY 1962	FY 1968	FY 1962	FY 1968
Man-equivalents	16.4	72.2	11.2	21.9
Expenditures (thousands)	143	1,370	64	440
Current state licenses or registrants	-	7,100[a]	-	2,327[b]
Inspections made in FY 1968	-	3,443	-	1,456[c]
Inspections in FY 1968 per man-equivalents	-	48	-	66
Licenses or registrants per man-equivalents	-	98	-	106

[a] Value estimated and based on data reported by the States for Fiscal Year 1968.

[b] Radium only.

[c] Only 522 inspections of radium facilities were made. The remainder were inspections of AEC licenses either conducted jointly with an AEC inspector or by the State only.

Most of the expenditures and manpower in Agreement State radioactive materials programs go into the control of the "agreement materials" (byproduct, source, and special nuclear), nevertheless, the expenditure and manpower in relation to the materials under direct State control in non-Agreement States was comparable to that in Agreement States. However, many non-Agreement States also involve themselves in the control of radioactive materials licensed by the AEC. Of 1,456 inspections made by these States during Fiscal Year 1968, 904 (62 percent) were inspection of facilities using radioactive material under the jurisdiction of the Commission.

A comparison of State manpower in radioactive materials programs during Fiscal Year 1968 and 1969 expressed as licenses or registrants per man-equivalent is shown in table 26. The value of 75 to 125 licenses or registrants per man-equivalent is considered as adequate staffing. It can be seen that there was considerable improvement in radioactive materials program staffing in Fiscal Year 1969, especially in the non-Agreement States; however, 7 Agreement States and at least 7 non-Agreement States were still inadequately staffed.

Table 26. Licenses or registrants per man-equivalent in State radioactive materials programs, FY 1968 and 1969

Range	Agreement States[a]		Non-Agreement States	
	FY 1968	FY 1969	FY 1968	FY 1969
<76	3	5	9	12
76-125	9	7	5	6
>125	6	7	16	7
Unknown	0	0	4	8

[a] Agreement States as of the end of each respective fiscal year.

The direct comparison of licensees or registrants per man-equivalent between Agreement and non-Agreement States gives a somewhat misleading picture of the adequacy of radioactive material program staffing in non-Agreement States. As mentioned previously, many of these States are devoting a significant portion of their available manpower to activities directly related to licenses under the control of the AEC. There are also several States expending considerable effort on preparing for an AEC – State Agreement.

Inspections

One of the best indicators of the quality of a State's radium control program is the number and frequency of surveys or inspections made of facilities using radium. An examination of the previously discussed table 21 indicates that during Fiscal Year 1968, the average radium reinspection frequency in non-Agreement States was once every four years while the average reinspection frequency for all licenses radioactive materials in Agreement States was once every two years. Table 27 and 28 present additional data on State radium inspections and reinspection frequencies. The State radium inspections shown in table 27 cover the period Fiscal Year 1965-1968; for more detailed information see Appendix A, table 14. Data available to the Bureau of Radiological Health prior to Fiscal Year 1965 is felt to be somewhat unreliable and was not included. However, it would appear that the number of inspections during the period Fiscal Year 1962-1965 increased steadily from very few in Fiscal Year 1962 to a maximum value in 1965 and has declined steadily since then.

Table 27. Reported State inspections of radium facilities; Fiscal Years 1965 – 1968

Fiscal Year	Total inspections[a]	Total facilities[b]	Percent inspected	States reporting data
1965	1,253	3,447	36	49
1966	1,174	3,124	38	49
1967	989	3,068	32	41
1968	996	3,297	30	44
AVERAGE	1,103	3,234	34	--

[a] Includes inspection data from only those States which reported a specific number of inspections of radium facilities. Some States did not keep inspection statistics specific to radium.

[b] Includes only radium facilities in those States reporting specific radium inspection data.

The total average percent of radium facilities inspected during Fiscal Year 1965-1968 was 34 percent. This would indicate an average reinspection frequency of once every three years which is considered adequate. However, as can be seen in table 28 (discounting States with an unknown average reinspection frequency), only 36 percent of the States reinspected every three years or less.

Table 28. Frequency of State reinspection of radium facilities

Reinspection frequency[a] (years)	States with inspection frequency in given range				
	FY 1965	FY 1966	FY 1967	FY 1968	Average[b]
<1.6	11	13	9	7	12
1.6-3	7	6	9	11	7
3.1-6	7	6	5	8	12
>6	24	24	18	18	17
Unknown	3	3	11	8	4
Reinspection frequency adequacy	**Percent of States**				
Adequate[c]	35	36	35	35	36
Inadequate	59	58	44	50	56
Unknown	6	6	21	15	8

[a] Frequency derived by dividing unity by the fraction of the total number of radium facilities inspected in each respective State during each fiscal year.

[b] Average was derived for each State individually. States having more than one year of unknown inspection data were counted as unknown in deriving average. The average for States with one year of missing data was based on data for the remaining three years.

[c] Adequate is considered to be equal to or less than three years.

State radium survey inadequacy is further documented by data obtained during the study of State control of health hazards from electronic product radiation and other types of ionizing radiation conducted in 1969. This study covering all of the State radiological health agencies indicated that for radium facilities under their control (1) only 69 percent had made initial inspections of 75 to 100 percent of these facilities, (2) 61 percent had made reinspections of less than 75 percent of the facilities, (3) 14 percent had never even made an initial inspection, and (4) 37 percent had made no reinspections.

Compliance

While inspections are one indication of the effectiveness of a State's radium control program, the degree of compliance with regulations or good safety practices which the State is able to obtain is the best indicator. Unfortunately, accurate and reliable information of this type is difficult to obtain. The Bureau of Radiological Health has attempted to obtain compliance information from the States beginning with its Fiscal Year 1967 inventory of State and local radiological health programs. The States were initially asked the number of radium facilities brought into compliance during the reporting year. In subsequent years they were asked the number found not in compliance during the reporting year and the number brought up to full compliance as well as the number brought up to partial compliance. The overall data supplied have had many shortcomings because of the inability of a large number of the States to supply any compliance data or to supply compliance data specific to radium. Nineteen States that had performed radium inspections during Fiscal Year 1967 reported compliance data specific to radium. Thirty-eight percent of the radium facilities inspected by these States were not in compliance and of these, only 43 percent were brought up to full compliance. Twenty-seven States reported that in Fiscal Year 1968, 47 percent of the radium facilities inspected were not in compliance while 63 percent of these were brought into full compliance. The methods of determining whether or not a facility was brought into compliance are not known and could vary from State to State. The seriousness of noncompliance is also not known and would be expected to vary from minor to quite serious. Although the percentage of facilities found not in compliance apparently increased from Fiscal Year 1967 to Fiscal Year 1968, because of uncertainties involved it cannot be determined whether or not the overall effectiveness of State radium control programs is increasing, declining, or remaining constant.

Conclusions

State financial and manpower resources expended on radioactive materials programs have continued to increase since Fiscal Year 1962. A large portion of this growth is attributable to the increase in the number of States which have assumed regulatory jurisdiction over byproduct, source, and special nuclear material through the AEC – State agreement mechanism.

Although the total man-equivalents devoted to radioactive materials programs in non-Agreement States seems adequate for control of radium, much of these resources are directed toward the control of radioactive materials licensed by the AEC and a lesser portion are expended in preparing for an AEC – State Agreement. Judged by the number of radium inspections made by all the States from Fiscal Year 1965-1968, 56 percent are doing an inadequate job. Of these, 5 were Agreement States. However, two of these were recent Agreement States which were doing an adequate job during Fiscal Year 1968. The overall inspection adequacy of 4 of the Agreement States could not be determined.

Suitable data on the effectiveness of State programs in terms of ability to obtain and maintain compliance with State regulations or standards are not available, however, a sample of States indicated that 38 to 47 percent of the radium facilities which they inspected were not in compliance at the time of inspection and that only 43 to 63 percent of these were brought into full compliance.

From the available information, it is apparent that many States should redefine their radioactive materials program goals. Rather than expending their limited resources on the control of AEC licensees, they should place more emphasis on control of radium and accelerator-produced radioactive materials which under the present regulatory framework can only be controlled by the States. Most States cannot afford the luxury of duplicating controls now exercised by the Federal Government. Such duplication quite often results in a lack of control being exercised over radioactive materials over which the States have direct and singular responsibility.

FEDERAL CONTROL OF NON-AEC CONTROLLED RADIOACTIVE MATERIALS

Direct Federal control over the use of non-AEC controlled radioactive materials exist at two levels:

1. Those applied external to a Federal agency, and
2. Those applied within the agency.

In addition, Federal agencies can and do exercise indirect effects which result in better controls being implemented by others.

No Federal agency has been charged with overall responsibility for control of radium and accelerator-produced radionuclides used within the Federal establishment. As a result, a uniform system of control has not been developed. Consequently, controls have been established within some agencies but not in others.

External Controls

Only four Federal agencies have regulations which allow direct, although limited, control of radium and accelerator-produced radionuclides exterior to their agency. These are as follows:

1. Department of Labor — through the authority of the Wash-Healey Public Contracts Act, has issued radiation protection regulations applicable to firms having contracts in excess of $10,000 with the U.S. Government. These regulations, applying to all radiation sources, are user oriented and virtually identical with the radiation protection section of the Atomic Energy Commission regulations (10 CFR Part 20).

2. Department of Transportation — has established user and carrier regulations for the interstate transportation of all radioactive materials. These regulations include shipping container, posting and labeling, and exposure rate requirements. State agencies have usually adopted DOT regulations for the control of the intrastate transportation of radioactive materials.

3. Food and Drug Administration — under the Federal Food, Drug and Cosmetic Act of 1938, as amended by the Kefauver-Harris amendments of 1962, is responsible for approving the safety and effectiveness of drugs

containing any radioactive materials used in the diagnosis and treatment of patients. However, by its very nature such control is limited to protection of the patient and does not extend to the user.

4. National Institutes of Health – through its Division of Biological Standards is responsible for establishing and maintaining, through licensure, standards of quality and safety of all biological products that come within the jurisdiction of the Public Health Service (vaccine, serums, antitoxins, and so forth). Thus, biological products of these types which contain radioactive materials come under the Federal jurisdiction.

Internal Controls

The Federal Radiation Council (FRC) formed in 1959 provides Federal policy on human radiation exposure. The FRC has issued certain recommendations which serve as guidance for all Federal agencies in the formulation of radiation control planning. Within the limits of this guidance, each individual Federal agency is free to institute its own controls in any manner felt necessary. However, no single agency is authorized to establish a uniform program to regulate all Federal use of radium and accelerator-produced radionuclides. As a result there probably exists within the Government the same range of controls as exist among the States in regulating these materials; i.e., a spectrum of programs from good to nonexistent. In contrast, Federal use of source, byproduct, and special nuclear materials is regulated by a single agency, the Atomic Energy Commission.

Indirect Controls

Many Federal agencies, although not having regulatory controls, can indirectly cause or be responsible for better controls being taken by others. Three agencies which have helped further radium and accelerator-produced radionuclide controls are:

1. Atomic Energy Commission – through their enactment of radiation protection standards have given State agencies a model to use for the control of non-AEC material. Through their Agreement State program they have given States the impetus to invest men and money in the "takeover" of agreement materials. This bolstering of State programs has resulted in an overall improvement in all radiation control.

2. Bureau of Radiological Health – through their technical assistance in such areas as standards, survey and testing procedures, source testing, waste disposal, emergency planning, and educational materials, as well as direct assistance in the form of grants, manpower, equipment,

and short training courses has provided States with the guidance for initiating and carrying out adequate control programs.

3. National Bureau of Standards — has been responsible for the publication of various handbooks stressing radiation control which provided assistance to the States as well as individual users. In addition, they have offered States a valuable service in providing accurate calibration of sources and survey instruments.

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REVIEW OF GAPS AND INCONSISTENCIES IN THE PRESENT CONTROL OF THE HEALTH HAZARDS OF RADIUM AND ACCELERATOR-PRODUCED RADIONUCLIDES

The gaps and inconsistencies existing in the present State and Federal control of the health hazard radium and of accelerator-produced radionuclides have been covered in the text of the report. This section serves to summarize these areas.

Gaps and Inconsistencies in Present State Control

1. Lack of control. Eleven States have not adopted radiation protection regulations. While seven of these States have at least made some inspections, relying on volumtary compliance by the user with nationally recognized standards, the remaining have absolutely no activities in this area.

2. Adoption of minimum uniform radiation protection regulations. There is a lack of uniformity and adequacy of regulations between States. Only approximately 50 percent of the States have adopted regulations which are compatible with the major radiation protection provisions of the "Model"(7). Users, regardless of their respective State, should be required to meet at least the same minimum standards. While the AEC can require compatibility of standards for agreement material, there is no such influence on non-agreement material.

Voluntary adoption of minimum, uniform, radiation safety standards including a consistent regulatory approach and effective enforcement action by all States has not come about. It is difficult and may be impossible to get adoption of such standards without some legal mechanism at the Federal level.

3. Regulatory approach. Existing radiation control programs lack uniformity in their regulatory approach. While some States license users, others merely register them. Consistency in this regard does not even exist among the Agreement States nor even among independent regulatory agencies in the same State. The "agreement materials" and accelerator-produced radioactive materials are licensed in all Agreement States, while radium is not.

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4. Compliance programs. States vary widely in the adequacy, effectiveness, and extent of their compliance activities. Reinspection frequency ranges from adequate to inadequate with only 35 percent of the States having an adequate frequency from Fiscal Year 1965-1968. Fourteen percent of the States have made no inspections. Some States do not follow up on items of noncompliance found during inspections. Regulations mean little without a vigorous and effective compliance program.

5. Product standards. Uniform controls should be applied to manufacturers of products containing radioactive material to insure that products meet certain minimum safety requirements. To provide this there must exist uniform standards which will be adhered to by all States and the regulatory authority to enforce them. At present such standards and uniform authority among the States does not exist and may be impossible to obtain under the present regulatory framework.

Gaps and Inconsistencies in Present Federal Controls

1. Internal Federal controls. No single Federal agency is authorized to establish programs to insure that the use of radium and accelerator-produced radionuclides in all Federal facilities meet minimal standards. Since Federal agencies are not subject to State authority, each individual agency or facility may independently establish their own control programs to the extent they feel necessary.

2. Products sold in interstate commerce. While the safety and effectiveness of all radiopharmaceuticals and radiobiological products are subject to Federal control, no other products containing non-AEC controlled radioactive material and sold in interstate commerce are required to meet Federal safety standards, regardless of whether they are imported or domestically produced. It would seem imperative that a national, centralized, control be exercised over these products rather than allow individual States or groups of States to make this decision. For not only does potential individual exposure have to be evaluated, but also the potential contribution to the total genetic pool. Added to this is the fact that only the Federal Government can exercise control over importation into the United States.

CONCLUSIONS

Although the use of radium is gradually being replaced by less hazardous radioactive materials, its use is still significant and will remain so for the foreseeable future. The relative hazard of this material coupled with its widespread and continued use in a diverse range of applications reinforce the necessity for its adequate control.

While the use of accelerator-produced radionuclides is still limited, their production and use is predicted to increase dramatically over the next several years, especially in the area of medical applications.

Responsibility for the control of all non-Federal use of radium and accelerator-produced radionuclides resides in the States. While some States have adequately met these responsibilities, many have not developed and enforced effective control programs. Not only have there been ineffective controls at the State level, but there may also be ineffective control at the Federal level, since no single Federal agency has been charged with the responsibility for developing uniform effective controls over all Federal use of these materials.

As a result of the diversity of control programs which have developed, there are at present many gaps and inconsistencies in the regulation of radium and accelerator-produced radionuclides. The most important among these are: (1) the disparity between State programs, (2) the lack of uniform control of Federal use, and (3) the lack of uniform, national, minimum safety standards for products containing such materials.

The Agreement States are spending in excess of $1 million annually on the control of "agreement materials" while the non-Agreement States are using a considerable portion of their resources on the regulation of radioactive materials which are directly regulated by the Atomic Energy Commission. The Public Health Service, previously through categorical formula matching grants and now through comprehensive health planning grants, has provided a significant portion of the funds used by the States for this purpose. Paragraph (i), Section 274 of the Atomic Energy Act authorizes the Atomic Energy Commission to provide States seeking an Agreement training and such other assistance as the Commission deems appropriate. This section further provides "Any such provision or assistance by the Commission shall take into account the additional expenses that may be incurred by an (Agreement) State..." To date only training and consultation services have been provided by the Commission. Should the Commission authorize assistance based upon additional expenses incurred by the Agreement States, then current State funds would be available for the control of non-AEC regulated materials. Such assistance would also encourage more States to enter into an AEC-State Agreement, thus avioding needless and wasteful dual regulation.

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APPENDIX A

SUPPLEMENTAL TABLES

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Table 1. Agreement States as of October 1, 1969

State	Effective date of agreement
Kentucky	3/26/62
California	9/1/62
Mississippi	7/1/62
New York[a]	10/15/62
Texas	3/1/63
Arkansas	7/1/63
Florida	7/1/64
North Carolina	8/1/64
Kansas	1/1/65
Oregon	7/1/65
Tennessee	9/1/65
New Hampshire	5/16/66
Alabama	10/1/66
Nebraska[b]	10/1/66
Washington	12/31/66
Louisiana	5/1/67
Arizona	5/15/67
Colorado	2/1/68
Idaho	10/1/68
North Dakota	9/1/69
South Carolina	9/15/69

[a] Only the New York City Health Department licenses radium. The New York State Departments of Health and Labor do not.

[b] Does not license radium.

Table 2. Radium-226 decay scheme

Radionuclide	Radiation emitted	Half-life
Radium-226	α,γ	1622y
↓		
Radon-222	α,γ	3.825d
↓		
Polonium-218 (Ra A)	α,β	3.05m
↓		
Lead-214 (Ra B)	β,γ	26.8m
↓		
Bismuth-214 (Ra C)	α,β,γ	19.7 m
↓		
Polonium-214 (Ra C^1)	α	1.64x10^{-4}s
↓		
Lead-210 (Ra D)	β,γ	19.4y
↓		
Bismuth-210 (Ra E)	α,β,γ	5.013d
↓		
Polonium-210 (Ra F)	α,γ	138.40d
↓		
Lead-206 (Ra G)	none	Stable

Table 3. Accelerator-produced radioactive materials (partial list)

Radio-nuclide	Half-life			
	Years	Days	Hours	Minutes
Al-26	7.4×10^5			
As-74		18		
As-76			26.5	
Au-195		183		
Au-196		6.2		
Au-198			65	
Be-7		53		
Bi-207	30			
C-11				20.5
Cd-109		470		
Ce-139		140		
Co-56		77.3		
Co-57		267		
Cr-51		27.8		
Cu-64			12.9	
F-18			1.87	
Fe-52			8.3	
Fe-55	2.7			
Ge-68		280		
Hg-197			65	
I-123			13	
Mn-52		5.7		
Mn-54		314		
Mn-56			2.58	
Mo-93m			6.9	
Na-22	2.58			
Na-24			15	
O-15				2.1
Pm-143		265		
Pm-144		380		
Pm-146		1600		
Rb-84		33		
Sr-85		64		
Sr-87			2.8	
Tc-95m		60		
Te-121m		150		
Ti-44	48			
Ti-200			26	
Ti-201			73	
Ti-202		12		
V-48		16.1		
V-49		330		
W-181		140		
Y-86			15	
Y-87			80	
Y-87m			14	
Y-88		106.7		
Z-63				38
Z-65		245		

Table 4. Radiation characteristics of radium-226 and substitutes

Isotope	Body Burden[a] (μCi)	I_γ $\left(\frac{\text{R-cm}^2}{\text{hr. mCi}}\right)$	I_β $\left(\frac{\text{rad. cm}^2}{\text{hr. mCi}}\right)$	Alpha $\left(\frac{\text{Mev}}{\text{dis}}\right)$	Half-life (yrs)	Relative hazard[b]	
						Internal	External
Alpha							
^{226}Ra*	0.1	8.25	580	23.95	1622	1.0	1.0
^{241}Am/^{237m}Np	0.1	0.14	0	5.53	470	4.41	.075
^{238}Pu	0.04	low	0	5.49	86	10.9	<<1.0
^{239}Pu	0.04	low	0	5.15	24,000	10.8	<<1.0
^{210}Pb*	0.03	.014	205	5.305	20	14.4	.0062
^{210}Po					.28		
Gamma							
^{137}Cs	30	3.0		0	27	.0082	1.0
^{60}Co	10	12.3		0	5.2	.0067	1.0
^{192}Ir	6	.46			.20	.30	1.0
Beta							
^{90}Sr/^{90}Y	2	.0017	370	0	28	.079	.0003
^{147}Pm/^{147}Sm	60	-	<2.8	0	2.5	.35	
Neutron			Neutron Yield m/sec-Ci				
^{226}Ra-Be	0.1	8.25	1.7×10^7		1622	1.0	1.0
^{239}Pu-Be	0.04	low	1.8×10^6		24,000	23.6	<<1.0
^{241}Am-Be	0.1	0.14	2.0×10^6		458	8.5	.145
^{252}CF	0.01	2.4	4.4×10^9	6.11	2.65	0.039	.0011

*chain

[a] Maximum permissible body burden

[b] Relative hazard has been compiled on the basis of the amount of substitute needed to give the same useful radiation as radium when used as an alpha, beta, gamma, or neutron source. In actual application, this ratio may vary somewhat because of the efficiency of the actual energy utilized.

Table 5. Radium licenses issued in sixteen Agreement States as of December 31, 1968

State	Total	No. of licenses by type		
		Medical	Non-medical	Out of State
Alabama	60	35	16	9
Arizona	11	5	5	1
Arkansas	47	28	13	6
California	393	170	210	13
Colorado[a]	9	4	5	0
Florida	90	60	25	5
Idaho	3	1	2	0
Kansas	62	24	30	8
Kentucky	50	30	16	4
Mississippi[a]	25	14	10	1
New Hampshire	17	7	10	0
North Carolina	92	53	35	4
Oregon	68	50	14	4
Tennessee[a]	35	12	21	2
Texas	293	141	144	8
Washington	46	25	17	4
Total	1301	659	573	69

[a] These values appear low; it is doubtful if all their radium licenses are included.

Table 6. Medical radium licenses in sixteen Agreement States as of December 31, 1968

State	Total	Type of licensee							
		Physicians				Institutions			Other
		Total	Location of licensee			Hospital	Clinic	University	
			Private	Clinic	Hospital				
Alabama	35	25	22	1	2	8	1	1	0
Arizona	5	4	4	0	0	1	0	0	0
Arkansas	28	17	13	0	4	4	6	1	0
California	170	83	58	0	25	80	3	1	3
Colorado[a]	4	0	0	0	0	3	0	1	0
Florida	60	39	24	1	14	17	2	1	1
Idaho	1	1	1	0	0	0	0	0	0
Kansas	24	12	5	2	5	6	3	1	2
Kentucky	30	8	7	0	1	17	1	2	2
Mississippi[a]	14	8	4	1	3	4	1	1	0
New Hampshire	7	3	0	0	3	3	1	0	0
North Carolina	53	21	12	0	9	31	0	1	0
Oregon	50	43	35	7	1	4	2	1	0
Tennessee[a]	12	6	5	0	1	5	0	1	0
Texas	141	88	60	13	15	31	13	3	6
Washington	25	18	15	2	1	3	2	1	1
Total	659	376	265	27	84	217	35	16	15

[a] These values appear low; it is doubtful if all their radium licenses are included.

Table 7. Nonmedical radium licenses in sixteen Agreement States as of December 31, 1968

State	Total	Type of licensee			
		Industrial	Governmental[a]	Educational	Other
Alabama	16	11	4	0	1
Arizona	5	2	1	0	2
Arkansas	13	9	1	2	1
California	210	106	25	24	55
Colorado[b]	5	4	0	1	0
Florida	25	11	4	6	4
Idaho	2	2	0	0	0
Kansas	30	19	1	5	5
Kentucky	16	9	2	2	3
Mississippi[b]	10	7	0	2	1
New Hampshire	10	6	2	2	0
North Carolina	35	19	1	7	8
Oregon	14	5	1	4	4
Tennessee[b]	21	12	2	1	6
Texas	144	112	7	13	12
Washington	17	7	3	4	3
Total	573	341	54	73	105

[a] Exclusive of Federal facilities.

[b] These values appear low; it is doubtful if all their radium is included.

Table 8. Possession limits on radium sources in sixteen Agreement States as of December 31, 1968

State	Activity by type of use			Total activity (mCi)
	Medical		Non-medical (mCi)	
	Ra (mCi)	Rn (mCi)		
Alabama	3,726	78	336.84	4,140.84
Arizona	247	-	11	258
Arkansas	6,078	201	2,691.50	8,970.50
California	24,399	1,350	9,657.64	35,406.64
Colorado[a]	890	150	48	1,088
Florida	12,187	1,420	1,302.67	14,909.67
Idaho	50	-	57	107
Kansas	4,592	232	10,443.83	15,267.83
Kentucky	4,009	700	744.76	5,453.76
Mississippi[a]	1,858	200	1,340.78	3,398.78
New Hampshire	955	-	55.70	1,010.70
North Carolina	6,657	218	10,877.63	17,752.63
Oregon	4,942	70	3,189.84	8,201.84
Tennessee[a]	1,083	787.5	141.69	2,012.19
Texas	26,733	1,332	54,973.85	83,038.85
Washington	3,161	115	725.01	4,001.01
Total	101,567	6,853.5	96,597.74	205,018.24

[a] These values appear low; it is doubtful if all their radium is included.

Table 9 . Radium possession by type of facility in certain non-Agreement states.

State	Population (millions)	Facility type									
		Medical		Industrial		Governmental[a]		Educational		Other	
		No. of facilities	Total activity[b]	No. of facilities	Total activity[b]	No. of facilities	Total activity[b]	No. of facilities	Total activity[b]	No. of facilities	Total activity[b]
Pa.	11.	170	22,308	112	>1535	4	>38	26	>247	8	>25
N. J.	6.8	93	10,622	45	>838	0	0	2	>250	5	UNK
Wis.	4.1	82	9,372	12	453	3	32	5	103	0	0
Ind.	4.9	51	5,955	24	152	0	0	7	90	0	0
Md.	3.5	38	6,459	8	259	1	5	4	42	0	0
Ohio	10.2	129	17,950	65	>7740[c]	9	45[c]	11	282[c]	4	>1000[c]
Mich.	8.2	71	9,587	33	451	7	88	7	60	0	-
Total	48.7	634	82,253	299	>11,428	24	208	62	1074	17	>1025

[a] Excludes Federal facilities

[b] Activity expressed in millicuries.

[c] Data from Ohio were presented using a range system; therefore, the exact values are not known. Approximations are used.

Table 10. Medical radium possession in certain non-Agreement States

Condition	State							
	Penn	N. J.	Wisc.	Ind.	Md.	Ohio	Mich.	Totals
Population X10^6	11	6.8	4.1	4.9	3.5	10.2	8.2	48.7

a. Ownership or long-term lease of sources

Condition	Penn	N. J.	Wisc.	Ind.	Md.	Ohio	Mich.	Totals
Number of facilities								
Hospital	127	69	16	18	18	73[a]	40	361
Private	37	3	23	11	20	56[a]	7	157
Total	164	72	39	29	38	129[a]	47	518
Number of sources								
Hospital	2800	1800	547	455	811	2179[b]	1226	9818
Private	278	12	209	81	25	485[b]	41	1131
Total	3078	1812	756	536	836	2664[b]	1267	10,949
Total activity (mCi)								
Hospital	19,192	8,167	3,534	3,040	5,374	13,160[c]	6,837	59,304
Private	2,516	160	1,538	715	1,085	4,740[c]	370	11,174
Total	21,708	8,327	5,072	3,755	6,459	17,950[c]	7,207	70,478

b. Short-term or "per case" lease of sources

Condition	Penn	N. J.	Wisc.	Ind.	Md.	Ohio	Mich.	Totals
Number of facilities								
Hospital	2	20	41	22	0	a	24	109
Private	4	1	2	0	0	a	0	7
Total	6	21	43	22	0	a	24	116
Total Activity (mCi)								
Hospital	200	2195	4100	2200	0	a	2380	11,075
Private	400	100	200	0	0	a	0	700
Total	600	2295	4300	2200	0	a	2380	11,775

c. Total medical radium sources

Condition	Penn	N. J.	Wisc.	Ind.	Md.	Ohio	Mich.	Totals
Activity (a + b) (mCi)	22,308	10,622	9,372	5,955	6,459	17,950[c]	9,587	82,253

[a] In Ohio owned or long-term leased could not be separated from short-term leased.

[b] Number of sources determined by using an average activity per source derived from data of remaining States.

[c] The data for Ohio are approximate since a range system was used in reporting data.

Table 11. Distribution of medical radium (owned and long-term leased) by source type[a] in certain non-Agreement States

State	Needles, Tubes, and Cells						Plaques						Nasopharyngeal applicators					
	Hospital		Private		Total		Hospital		Private		Total		Hospital		Private		Total	
	No.	Act.[b]	No.	Act.[b]	No.	Act.[b]	No.	Act.[b]	No.	Act.[b]	No.	Act.[b]	No.	Act.[b]	No.	Act.[b]	No.	Act.[b]
Pa.	2345	17570	252	2019	2597	19589	14	109	13	135	27	244	2	100	8	375	10	475
N. J.	1800	167	10	100	10	8267	0	0	1	10	1	10	0	0	1	50	1	50
Wis.	537	419	197	1373	34	4792	9	65	11	115	20	180	1	50	1	50	2	100
Ind.	455	3015	77	685	532	3700	3	25	4	30	7	55	0	0	0	0	0	0
Md.	805	4974	0	0	805	4974	0	0	4	35	4	35	8	400	21	1050	29	1450
Mich.	1214	6667	36	350	1250	7017	10	110	3	20	13	130	2	60	0	0	2	60
Total	7156	**43812**	572	4527	7728	48339	36	309	36	345	72	654	13	610	31	1525	44	2135

[a] Includes only sources of known source type.

[b] Act. - Activity in millicuries.

Table 12. Nonmedical radium sources in certain non-Agreement States

State	Industrial radiography		Well logging		Calibration and reference		Fixed gauge		Mobile gauge		Static eliminator		Gas and aerosol detector		Chromatoraphy		Other and not identified	
	No.	Act. (mCi)	No.	Act. (mCi)	No.	Act. (mCi)	No.	Act. (mCi)	No.	Act. (mCi)	No.	Act. (mCi)	No.	Act. (mCi)	No.	Act. (mCi)	No.	Act. (mCi)
Pa.	4	225	3	35	99	263	116	138	13	26	208	333	622	24	10	1	1613	827
N.J.	0	0	0	0	24	66	67	131	5	20	5	1	22	21	10	1	42	847
Wis.	2	400	0	0	8	89	10	4	6	22	5	4	0	0	0	0	16	70
Ind.	0	0	0	0	12	27	48	72	10	7	8	4	164	3	2	<1	51	129
Md.	2	225	0	0	36	7	0	0	1	5	0	0	0	0	0	0	18	69
Mich.	1	300	12	81	15	3	48	60	28	11	6	<1	1405	53	1	<1	27	69
Totals	9	1150	15	116	194	455	289	405	63	91	232	342	2213	101	23	2	1767	2011

Table 13. Principal brachytherapy procedures performed during 1966 - SRI data (58)

Treatment type	Radionuclide	Total[a] respondents	Physicians reporting use	Annual treatments	Total[b] projected annual treatments
Intracavitary	^{226}Ra ^{60}Co ^{137}Cs	734 283 22	543 90 16	15,700 2,737 548	42,432 5,069 1,015
Interstitial (temporary)	^{226}Ra ^{60}Co ^{192}Ir	604 258 51	276 31 32[c]	4,152 547 404[c]	11,222 1,013 748[c]
Interstitial (permanent)	^{222}Rn ^{198}Au ^{192}Ir	436 20 51	158 12 32[c]	3,069 106 404[c]	8,295 196 748[c]
Ophthalmic	^{226}Ra ^{90}Sr	7 483	6 295	100 11,785	270 21,824
Dermatological	^{226}Ra ^{90}Sr	378 8	109 7	5,582 1,182	15,086 2,189
Nasopharyngeal	^{226}Ra ^{90}Sr	324 6	62 6	2,840 678	7,676 1,256
Total ^{226}Ra & ^{222}Rn Byproduct				31,443 17,987	84,981 33,310

[a] Includes those who reported prior use but no current use.

[b] Total projected annual treatments for by-product material based on 54% answering population. Projected annual treatments for radium based on 37% of a total of 2500 medical radium facilities and assuming that each answer represented one facility.

[c] Temporary and permanent were not separated.

Table 14. State inspections of licensed or registered radium facilities from FY 1965 through FY 1968

State	Number of inspections of radium facilities				Facilities licensed or registered[a]	State	Number of inspections of radium facilities				Facilities licensed or registered[a]
	FY 65	FY 66	FY 67	FY 68			FY 65	FY 66	FY 67	FY 68	
Total	1253	1174	989	996	4153						
Ala.	45	50	NS	38	52	Neb.	0	0	4	2	59
Alaska	0	0	2	UNK	2	Nev.	0	0	0	1	5
Ariz.	0	0	0	2	5	N. H.	8	15	27	NR	13
Ark.	75	60	36	45	45	N. J.	35	63	135	157	145
Calif.	NS	NS	NS	NS	381	N. Mex.	7	12	11	2	26
Colo.	UNK	5	5	NS	40	N. Y.	131	121	101	93	436
Conn.	43	35	28	NR	50	N. C.	18	51	NS	24	44
Del.	3	0	3	2	16	N. Dak.	0	4	0	6	17
D.C.	6	10	13	6	16	Ohio	99	20	12	3	218
Fla.	47	78	NS	60	85[b]	Okla.	76	37	44	43	112
Ga.	35	40	41	25	46	Oreg.	4	6	NS	10	47
Hawaii	1	0	1	0	1	Pa.	230	UNK	40[c]	63	363
Idaho	0	1	6	0	11	R. I.	0	10	0	UNK	45
Ill.	105	88	115	91	348	S. C.	0	4	7	14	31
Ind.	24	71	32	33	82	S. D.	0	0	0	0	22
Iowa	0	1	0	0	57[d]	Tenn.	6	36	NS	35	43
Kans.	55	69	NS	26	68	Texas	NS	UNK	NS	NS	285[b]
Ky.	32	48	NS	9	40	Utah	0	0	UNK	0	0
La.	0	0	2	64	83	Vt.	0	0	0	6	6
Maine	19	8	1	2	21	Va.	0	0	32	0	61
Md.	5	5	30	15	51	Wash.	2	0	NS	NS	40
Mass.	34	97	80	13	176	W. Va.	0	8	0	3	49
Mich.	14	18	127	62	117	Wis.	5	19	4	2	100
Minn.	22	14	6	7	36	Wyo.	0	0	0	0	6
Miss.	56	62	39	34	60	P. R.	7	6	5	1	7
Mo.	0	2	0	0	24						
Mont.	4	0	0	0	60						

[a] During FY 1968.

[b] Data taken from licenses published in the Atomic Energy Clearing House.

[c] Data available from the Philadelphia Health Department only.

[d] Number estimated since State did not know.

NS - Radium inspection not separated from other radioactive materials.

NR - Not reported.

UNK - Unknown.

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APPENDIX B

LETTERS, QUESTIONNAIRES, AND MAILING LIST

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DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
ROCKVILLE, MARYLAND 20852

Bureau of
~~NATIONAL CENTER FOR~~
RADIOLOGICAL HEALTH
12720 Twinbrook Pkwy.

REFER TO: DMRE

Addressees;
U.S. manufacturers, suppliers, and
importers of radium sources and/or
devices containing radium.

Dear Sir:

The Bureau of Radiological Health would like your cooperation in acquiring information relative to the magnitude and extent of the use of radium in the United States. The information requested on the attached questionnaire will be used in conjunction with information requested from other organizations in a report to Congress by the Secretary of the Department of Health, Education, and Welfare to be submitted on or before January 1, 1970. The Secretary is required to make the report pursuant to paragraph (a) of Section 357, Public Law 90-602 (copy attached).

The information requested herein will be used specifically in relation to subparagraph (1) of the aforementioned paragraph (a) which requires "(1) A study of present State and Federal control of health hazards from electronic product radiation and other types of ionizing radiation, which study shall include, but not be limited to--(A) control of health hazards from radioactive materials other than materials regulated under the Atomic Energy Act of 1954."

Confidential information provided will be handled in accordance with Title 18, section 1905 of the U.S. Code.

It would be appreciated if you could complete and return the questionnaire at your earliest convenience. Any additional information you could provide such as catalogs, brochures, etc. would prove most helpful.

Sincerely yours,

John C. Villforth, Chief
Division of Medical Radiation Exposure

Bureau of Budget No. 85-S69005
Expires 30 November, 1969

Return to:
Division of Medical Radiation Exposure
Bureau of Radiological Health
12720 Twinbrook Parkway
Rockville, Maryland 20852

QUESTIONNAIRE FOR U.S. MANUFACTURERS. SUPPLIERS. AND IMPORTERS OF RADIUM SOURCES AND/OR DEVICES CONTAINING RADIUM

I. Radium Source Manufacturers, Suppliers and Importers

A. Quantity of Sources Sold

Type	Quantity Sold During 1967 & 1968	
	No. of Sources	Total Act.(mCi)
MEDICAL		
a. tubes, needles, cells		
b. plaques		
c. nasopharyngeal		
d. other		
NON-MEDICAL (List each type)		
a.		
b.		
c.		
d.		
e.		
LUMINOUS COMPOUND (List each type)		
a.		
b.		
c.		
d.		

B. Leased Radium Sources

Type	Sources Presently on Lease		Estimated Annual Demand	
	No. of Sources	Total Act.(mCi)	No. of Sources	Total Act.(mCi)
a.				
b.				
c.				
d.				
e.				
f.				

C. Past Sales of Radium Sources*

Category	No.	Total Act.(mCi)
1. Medical Sources		
2. Non-medical Sources		
3. Luminous compound		

II. Manufacturers, Suppliers, and Importers of Devices Containing Radium

A. Devices Containing Sealed Radium Sources

Type of Device	Model No.	Source		Quantity Sold			
				____* thru 1966		1967 & 1968	
		Supplier	Model No.	No.	Total Act.(mCi)	No.	Total Act.(mCi)
a.							
b.							
c.							
d.							
e.							
f.							

B. Devices Containing Unsealed Radium

Type of Device Containing Unsealed Source	Source Supplier	Quantity Sold			
		____* thru 1966		1967 & 1968	
		No.	Total Act.(mCi)	No.	Total Act.(mCi)
a.					
b.					
c.					
d.					
e.					
f.					
g.					

*Note: For Sales figures prior to 1967, record the initial year of the time period covered. Provide data, actual or estimated, as far back as sales records will permit.

III. General

A. Is your company presently licensed by an Agreement State to manufacture or supply devices and/or sources listed above? Yes___State_____No___

B. Are radium sealed sources leaving your facility routinely leak tested? Yes___Some___No___

C. Is prototype testing carried out on each radium source or device model? Yes___Some___No___

D. Over the next 5 years do you expect the quantity of radium sold or leased annually by your company to: Increase___Remain Constant___Decrease___.

E. Does your company use in products or supply for commercial sale, accelerator produced radioactive materials? Yes___No___ If yes, indicate sales under I.A. reporting the radionuclide in place of the type.

Company______________________________by______________________________
(name)

____
(Title)

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
ROCKVILLE, MARYLAND 20852

Bureau of
XXXXXXXXXXXXXX
RADIOLOGICAL HEALTH
12720 Twinbrook Pkwy.

REFER TO: DMRE

Addressees;
Foreign manufacturers and suppliers
of radium sources and/or devices
containing radium.

Dear Sir:

The Bureau of Radiological Health would like your cooperation in acquiring information relative to the magnitude and extent of the use of radium in the United States. It has been reported that your organization produced gauges containing radium. If these gauges or other sources or devices containing radium are marketed in the U.S.A., it would be most helpful if you could complete and return the enclosed questionnaire. This information will be used in conjunction with information requested from other organizations in a report to Congress by the Secretary of the Department of Health, Education, and Welfare to be submitted on or before January 1, 1970. The Secretary is required to make the report pursuant to paragraph (a) of Section 357, Public Law 90-602 (copy attached).

The information requested herein will be used specifically in relation to subparagraph (1) of the aforementioned paragraph (a) which requires "(1) A study of present State and Federal control of health hazards from electronic product radiation and other types of ionizing radiation, which study shall include, but not be limited to--(A) control of health hazards from radioactive materials other than materials regulated under the Atomic Energy Act of 1954."

Confidential information provided will be handled in accordance with Title 18, Section 1905 of the U.S. Code.

It would be appreciated if you could complete and return the questionnaire at your earliest convenience. Any additional information you could provide such as catalogs, brochures, etc. would prove most helpful.

Sincerely yours,

John C. Villforth, Chief
Division of Medical Radiation Exposure

Return to:
Division of Medical Radiation Exposure
Bureau of Radiological Health
12720 Twinbrook Parkway
Rockville, Maryland 20852

QUESTIONNAIRE FOR FOREIGN MANUFACTURERS AND SUPPLIERS OF RADIUM SOURCES AND/OR DEVICES CONTAINING RADIUM

Does your company sell radium sources and/or devices containing radium in the U.S.A.? Yes___ No___

If yes, complete the following:

1. Name(s) and address(es) of the United States importers of radium sources and/or devices manufactured or supplied by your company.

2. Sources and/or devices shipped to the United States by your company.

Type	Number	Total Activity (milligrams)

Company________________________________ by________________________________
(name)

____
(Title)

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
ROCKVILLE, MARYLAND 20852

Bureau of
~~NATIONAL CENTER FOR~~
RADIOLOGICAL HEALTH
12720 Twinbrook Pkwy.

REFER TO: DMRE

Addressees:
Suppliers of accelerator
produced radioactive
materials.

Dear Sir:

The Bureau of Radiological Health would like to obtain your cooperation in acquiring information relative to the magnitude and extent of the use of accelerator produced radioactive materials in the United States. This information will be used in conjunction with information requested from other organizations in a report to Congress by the Secretary of the Department of Health, Education, and Welfare to be submitted on or before January 1, 1970. The Secretary is required to make the report pursuant to paragraph (a) of Section 357, Public Law 90-602 (a copy of which is attached).

The information requested herein will be used specifically in relation to subparagraph (1) of the aforementioned paragraph (a) which requires "(1) A study of present State and Federal control of health hazards from electronic product radiation and other types of ionizing radiation, which study shall include, but not be limited to--(A) control of health hazards from radioactive materials other than materials regulated under the Atomic Energy Act of 1954."

It would be appreciated if you could complete and return the questionnaire at your earliest convenience.

Sincerely yours,

John C. Villforth, Chief
Division of Medical Radiation Exposure

Enclosure

Return to:
Division of Medical Radiation Exposure
Bureau of Radiological Health
12720 Twinbrook Parkway
Rockville, Maryland 20852

QUESTIONNAIRE FOR SUPPLIERS OF ACCELERATOR PRODUCED RADIOACTIVE MATERIALS

1. Quantity Sold Prior to 1967*

Isotope	Quantity (mCi)		
	Medical	Non-Medical	Total

2. Quantity Sold During 1967-1968*

Isotope	Quantity (mCi)		
	Medical	Non-Medical	Total

3. Projected Quantity Sold Annually by 1971*

Isotope	Quantity (mCi)		
	Medical	Non-Medical	Total

4. Do you require evidence of a State license before shipping accelerator produced material to a customer in an Agreement State? Yes___No___

Company________________________________by________________________________
(name)

____
(Title)

*Isotopes with half-lives of less than 30 days may be grouped together as "short lived" for reporting purposes.

TECHNICAL REPORTS

(continued from inside of front cover)

MORP 68-8	Dental X-ray Teaching and Training Replica (PB 182 854 $3.00)
MORP 68-9	Development and Evaluation of an Automatic Collimator for Medical Diagnostic X-ray Machines (PB 180 528 $6.00)
MORP 68-10	Survey of the Use of Radionuclides in Medicine: Preliminary Report (Superseded by BRH/DMRE 70-1)
MORP 68-11	Dental Surpak Summary Report (PB 184 356 $3.00)
MORP 68-12	Particle Accelerator Safety Manual (Supt. of Doc., GPO-$1.25) (PB 178 325 - microfiche only)
MORP 68-13	PHS Film Badge Program (In preparation)
MORP 68-14	Radiation Safety Recommendations for X-ray Diffraction and Spectrographic Equipment (PB 182 558 $3.00)
DMRE 69-1	Report of the Task Force on X-ray Image Analysis and Systems Development (PB 184 130 $3.00)
DMRE 69-2	Symposium on Past, Present, and Future State X-ray Programs (PB 184 481 $3.00)
DMRE 69-3	Medical Radiation Information for Litigation (PB 187 697 $6.00)
BRH/DMRE 70-1	Survey of the Use of Radionuclides in Medicine (PB 188 619 $3.00)
BRH/DMRE C70-2	Automatic Data Processing System Study for Massachusetts General Hospital Diagnostic Radiology Department (PB 193 937 $3.00)
BRH/DMRE 70-3	A Training Manual for Nuclear Medicine Technologists (Supt. of Doc., GPO-$1.75) (PB 196 441 - microfiche only)
BRH/DMRE 70-4	Cyclotron Production of ^{123}I - an Evaluation of the Nuclear Reactions Which Produce This Isotope (PB 196 162 $3.00)
BRH/DMRE 70-5	The Use of Radioactive Materials in Gas Chromatography (PB 195 970 $3.00)
BRH/DMRE 71-1	Summary of Federal Regulations for Packaging and Transportation of Radioactive Materials (Supt. of Doc., GPO-$0.50) (PB 197 698 - microfiche only)
BRH/DMRE 71-2	X-ray Fluoroscopic Screens - History, Crystal Kinetics, Preliminary Report on "Aging" (Supt. of Doc., GPO-$0.60) (PB 198 239 - microfiche only)
BRH/DMRE 71-3	Storage and Handling Devices for Radium